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Nationwide Urban Runoff Program
Washington Metropolitan Area Urban Runoff Demonstration Project
Final Report, 1979-1982

Metropolitan Washington Council of Governments
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WASHINGTON METROPOLITAN AREA
URBAN RUNOFF DEMONSTRATION PROJECT

A Final Report

Prepared for

Department of Environmental Programs
Metropolitan Washington Council of Governments
1875 Eye Street, N.W.
Washington, D.C. 20006

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This report was prepared by Thomas F. Quasebarth, NVPDC Environmental Planner Engineer. The study was carried out under the overall direction of John P. Hartigan, P.E., former Director of the Regional Resources Division, NVPDC. Assistance with the application of nonparametric statistical techniques was provided by Dr. Elizabeth M. Southerland, former NVPDC Environmental Engineer. David J. Biggers, former NVPDC Water Resources Engineer, directed the first two years of the study. Alan C. Cavacas and John A. Friedman, P.E., NVPDC Water Resources Engineers and Todd Scott, former NVPDC Research Analyst provided technical assistance. The assistance of NVPDC interns Cynthia Birch and Susan Lees was invaluable. Special thanks go to Carol Erbe and Betty Fox for typing and preparation of tables.

EXECUTIVE SUMMARY

I. INTRODUCTION

Under the Washington Metropolitan Area's Urban Runoff Demonstration Project, monitoring data from twelve urban test watersheds was analyzed to correlate urban land use and nonpoint pollution loadings in runoff and to evaluate the effectiveness of urban Best Management Practices (BMPs). Monitoring data was collected for almost 600 station-storms during the period June 1980 through December 1981. To assess the impact of atmospheric loadings in urban runoff, almost 300 wetfall/dryfall samples were collected at four stations located throughout the metropolitan area. The project was sponsored by the U.S. Environmental Protection Agency as part of its Nationwide Urban Runoff Program (NURP). This program included twenty-eight similar planning efforts across the country which focused on urban stormwater and water quality.

The test watersheds in the Washington Metropolitan Area which were selected for monitoring were small, ranging from approximately 4 to 80 acres and to the extent possible, watersheds selected were representative of a single homogeneous urban land use which facilitated land use/nonpoint pollution loading correlations. All test watersheds were served by urban BMPs. Urban BMPs are low-structural management alternatives for controlling urban runoff pollution. Types of BMPs which were monitored included 3 wet ponds, 3 dry ponds, 2 infiltration pits, 3 grassed swales and 1 porous pavement site. Urban impoundments such as wet/dry ponds detain stormwater and release it at a controlled rate. Downstream water quality is improved as a result of sedimentation, biological uptake of nutrients, and chemical transformations of pollutants. Infiltration pits are gravel or sand filled pits situated to receive stormwater runoff from impervious areas. Runoff is detained and allowed to infiltrate into the soil. At the grassed swale BMPs, traditional curb and gutter installations were replaced by grassed drainage channels to lower runoff velocities and to enhance infiltration and remove pollutants. Porous pavement uses a special asphaltic paving material to allow stormwater to infiltrate at a high rate. This practice detains stormwater in a high void aggregate base and can increase infiltration into the soil.

To assess BMP pollutant removal efficiencies, the Washington Area NURP monitoring sites were paired to compare uncontrolled runoff to runoff which received BMP 'treatment'. For the wet/dry ponds, this was accomplished by monitoring both the inflow and outflow to the pond. Other BMPs such as infiltration pits, grassed swales, and porous pavement sites do not lend themselves to direct measurement of pollutant inflows or uncontrolled runoff from the land surface. Pollutant loads monitored at sites with these BMPs were compared to uncontrolled runoff loadings from different sites of similar land uses.

II. DATA MANAGEMENT ACTIVITIES

A computer-based data management system which relied on the Statistical Analysis System (SAS) was developed to screen the raw data and to perform statistical analyses. Complete runoff and wetfall/dryfall summaries are included in the appendices of the report.

All relevant information regarding the physical characteristics of the test watersheds was also compiled. This data included drainage areas, impervious land cover, and soils characteristics. BMP design features such as storage capacity, and design operating performance data were also compiled. Numerous site visits were conducted to confirm this information.

III. VERIFICATION AND REFINEMENT OF LAND USE-NONPOINT POLLUTION RELATIONSHIPS FOR THE METROPOLITAN REGION

One of the major objectives of the NURP study is to compare the NURP land use/nonpoint pollution relationships with relationships developed from an earlier '208' field study which was conducted in 21 Northern Virginia watersheds between June 1976 and May 1977. As part of the 208 study, watershed models were calibrated to derive annual nonpoint pollution rates (i.e., lbs/ac/yr) for a year of "average" wetness. Although no modeling was done during the NURP study, the significantly larger NURP database was used to test the transferability of the 208 relationships in applications to Maryland and District of Columbia watersheds and the influence of different hydrometeorologic conditions was assessed.

Unit Area Loading Comparisons

Comparisons between the NURP and 208 datasets were made based on event mean concentrations (i.e., the total pollutant load divided by the total runoff volume) and unit area loads (e.g., lbs/acre). Because different sampling techniques were used in each study, it was determined that unit area loading rates were more appropriate for statistical comparisons. Data from four urban land use categories was available for comparison: (1) large lot single family, (2) medium density, (3) townhouse/garden apartment, and (4) shopping center. All sites within a given land use category were pooled for each study.

The NURP and 208 datasets were subjected to a series of parametric and non-parametric statistical tests which are detailed in the report. The purpose of the tests was to determine the frequency distribution, or the central value (i.e., the mean or median) for selected pollutants. Datasets were screened to ensure that runoff volumes were similar in both datasets prior to performing comparisons between pollutant loadings.

The results of the statistical comparisons are summarized below:

- o Total Phosphorus: For all residential land use categories, no significant difference was found between the NURP and the 208 land use datasets. Lower total-P loadings were noted at the NURP shopping center sites. This may be attributed to the BMP's serving all NURP shopping center sites.

- Total Nitrogen: There were no significant differences detected for any of the four land uses considered.

- Extractable Zinc: Loadings of extractable zinc noted at the NURP land use categories were significantly lower. For large lot and medium density single family, NURP loadings were 50%* of 208 loadings. For townhouse/garden apartment, NURP loadings were 66% of 208 loadings.

- Extractable Lead: Lower extractable lead loadings were detected in the NURP land use categories. For large lot and medium density single family, NURP loadings were 50% of 208 loadings. For townhouse/garden apartment NURP loadings were 66% of 208 loadings.

- Total Suspended Sediment: Much lower sediment loadings were noted at the NURP sites. NURP large lot single family loadings were 37% of 208 loadings while NURP medium density loadings were 25% of 208 loadings. For the townhouse category, NURP loadings were 33% of 208 loadings.

- Pollutant Fractions: The NURP land use datasets exhibited consistently higher fractions, both soluble and inorganic, for nitrogen and phosphorus. Soluble zinc fractions are higher for all NURP land use datasets. These results are notable because although total-P and total-N loadings were not different, the soluble and inorganic fractions are higher. The soluble and inorganic forms of nitrogen and phosphorus are most readily available for algal uptake. These results are consistent with the lower TSS loadings described above.

IV. ATMOSPHERIC LOADINGS

Four wetfall/dryfall samplers were located at three sites in the metropolitan area. The stations were located at Haines Point, D.C., Stedwick, Md. and two stations at Burke Centre, Va., one roof mounted and one mounted at ground level.

Wetfall Analysis

Results of the wetfall analyses are summarized below:

- Phosphorus forms: Wetfall potentially contributes a significant amount of the total-P loadings found in runoff. Based on comparisons of synoptic events, wetfall loadings are 10%-15% of runoff loadings. Organic-P forms are typically 75%-85% of the total-P load.

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*Differences are expressed as the ratio of the NURP median value to the 208 median value.

- Nitrogen forms: Comparisons of synoptic events indicate that wetfall loads exceed runoff loads in many cases. Total kjeldahl nitrogen accounts for 40%-50% of the total-N load.
- Extractable Zinc: Wetfall loads exceed runoff loads at all stations except the Burke roof level station. Automobile tires which are commonly named as a source of zinc would fit this pattern as a ground level source.
- pH: Laboratory measurement of pH indicates that rainfall in the metropolitan area is quite acidic. Mean pH values are between 4.0 and 4.1 as compared to the pH of unaffected rainwater which should not be lower than 5.6 (e.g., due to natural mechanisms). Similar pH measurements in runoff indicate that acid rain is not a problem in runoff; pH in runoff ranges from 6.8 to 7.0 which is well within the neutral (well-buffered) range.

Dryfall Analysis

Dryfall data was statistically screened to check for seasonal and regional differences in dryfall deposition. Seasonal differences detected were inconsistent and, given the relatively short monitoring period, not conclusive. Regional differences were detected particularly for the phosphorus and nitrogen forms. The highest dryfall loadings were associated with the most urbanized site located within the Washington, D.C. city limits. The lowest dryfall loadings were associated with the lowest density townhouse site. Intermediate loadings were noted at shopping center sites. These findings probably correlate very well with local traffic volumes, although traffic data was not available.

V. EFFICIENCY OF POLLUTANT REMOVAL BY MONITORED BMP'S

Detention Basin Performance

Detention basin performance was evaluated based upon comparisons of synoptic storm event data (e.g., only those events which were completely monitored at the inflow and the outflow station). Of the 111 synoptic pairs which were monitored, only 45 were acceptable. The remaining events were characterized by flow discrepancies greater than 30% between the inflow and outflow stations.

The important physical characteristics and the number of synoptic events used in the detention basin analysis are summarized below:

SITE	BMP	DRAINAGE AREA	STORAGE VOLUME	# OF SYNOPTIC EVENTS
Burke Pond	Wet Pond	27.1 Ac.	1.4 in.	13
Westleigh	Wet Pond	47.9 Ac.	1.8 in.	16
Lakeridge	Dry Pond (Peak Shaving)	88.4 Ac.	0.3 in.	16
Stedwick	Dry Pond (24 Hour Design Detention)	34.4 Ac.	0.7 in.	0

Stedwick, the only high detention dry pond, was not included in the analyses for two reasons: (1) a leak in the outlet structure resulted in detention times typical of a peak shaving facility (e.g., 4-6 hours), and (2) severe flow gaging problems were encountered at the site, possibly as a result of the close proximity of high voltage power lines.

Results of the wet pond analyses were quite good. Although significant variation was noted on an individual storm event basis, long term pollutant removal efficiencies based on analysis of synoptic events are summarized below:

	POLLUTANT REMOVAL EFFICIENCY (%)					
POND	TSS	TP	TSP	TN	TKN	NO23
Burke	27%	67%	78%	29%	14%	67%
Westleigh	78%	63%	80%	24%	18%	39%
Burke + Westleigh	54%	66%	78%	28%	15%	60%

The very high removal of phosphorus forms can be attributed to biological processes, (e.g., algal uptake, wetland vegetation, and rooted aquatic plants).

Pollutant removal efficiencies at Lakeridge, the peak shaving dry pond facility, were low or negative for most constituents. High release rates, low detention times, and lack of quiescent conditions are probable explanations for the poor removal efficiencies noted at this site which was not designed to provide water quality benefits.

Wet Pond Pollutant Removal Regression Models

Linear regression models were developed to predict pollutant removal efficiencies from: (1) storm event inflow volumes (inches), (2) storm event outflow volumes, and (3) inflow event mean concentrations. Correlations were fairly good for most constituents.

Volume Control Assessments

Evaluation of volume control BMPs such as infiltration pits and porous pavement was based on comparison with sites of similar land use without BMP controls. Only shopping center and townhouse land use categories were available for comparison.

Shopping Center. An uncontrolled NURP site was not available in this category; therefore, comparisons were made with 208 sites. Data from the NURP shopping center sites which included one infiltration pit BMP and one porous pavement BMP was pooled for comparison. Removal rates which were computed from the median loading rates are summarized below:

TSS:	88%
Total-P:	55%
Total-N:	-7%
COD:	72%
EPb:	50%
EZn:	75%

Townhouse. Loading data from Dandridge, a NURP townhouse site, served by infiltration pits was compared to two NURP townhouse sites which were not served by BMPs.

Results of these comparisons showed significant removal only for TSS (64% removal). For the nitrogen and phosphorus forms, removals were very low or negative. A reevaluation of the sites indicate that other factors may be biasing the comparisons. The BMP site was characterized by (1) much higher percent imperviousness, and (2) only 48% of the drainage area at the site received BMP treatment.

Grass Swale Assessments

Three of the NURP monitoring sites drained large lot or medium density single family subdivisions which were served by roadside grass swale instead of curb and gutter systems. Assessments of the pollutant removal efficiencies were made by comparisons of synoptic events at other NURP sites of similar land use, drained by curb and gutter installations.

The results of a statistical analysis of the 'grass swale' and the 'curb and gutter' datasets showed no significant differences. In other words, no significant pollutant removal could be detected at the grass swale sites. Rough calculation suggests that the typical length of time that runoff was in contact with the swale is 5 minutes or less. Effective pollutant removal would require contact times on the order of one hour. Grass swales are effective in reducing the impervious fraction and therefore can contribute to lower runoff volumes as well as reduced runoff velocities.

I. INTRODUCTION

Under the Washington Metropolitan Area's Urban Runoff Demonstration Project, monitoring data from twelve test watersheds was analyzed to correlate urban land use and nonpoint pollution loadings in runoff and to evaluate the effectiveness of urban best management practices (BMP's). Monitoring data was collected for almost 600 station-storms during the period June 1980 through December 1981. The project was sponsored by the U.S. Environmental Protection Agency (USEPA) as part of its Nationwide Urban Runoff Program (NURP). The Northern Virginia Planning District Commission (NVPDC) performed data management and statistical analyses in association with the Metropolitan Washington Council of Governments (MWCOG), Water Resources Planning Board (WRPB) and the Virginia Polytechnic Institute and State University (VPI&SU) who carried out the monitoring program. The purposes of the study described herein are: (1) to refine and verify existing land use/nonpoint pollution relationships which were produced by the metropolitan Washington's initial 208 planning efforts (1,2), and (2) to develop information on the nonpoint pollution removal effectiveness of urban BMP's.

Scope of Report

This report has been prepared pursuant to Tasks 2a, 3d, 5e, and 6d of the NVPDC-COG contract of June 17, 1980.

The first section of this report details the data management activities which were performed on the NURP monitoring data. Summaries of the physical characteristics of the BMP monitoring sites, as well as the water quality and wetfall/dryfall data, are presented.

The second section of the report summarizes the statistical analyses undertaken to refine and verify land use-nonpoint pollution relationships developed from the 208 field study in 1976-1977. Refinements to the 208 relationships were made based on comparisons of unit area loads (e.g., lbs/acre).

The third section of the report summarizes the results of the analyses of wetfall/dryfall data. Results of tests designed to detect regional and seasonal differences in atmospheric loadings are presented. The impacts of wetfall on runoff pollution loadings are assessed.

The fourth section of the report summarizes the analyses undertaken to quantify the pollutant removal efficiencies of monitored BMPs. For detention basins, the analysis focused on pollutant loadings monitored during synoptic events at the basin inflow and outflow. For other BMPs such as infiltration pits, porous pavement and grass swales, assessments were made based on comparisons with other sites of similar land use without BMP controls.

II. DATA MANAGEMENT ACTIVITIES

BMP Characteristics and Drainage Area Information

Throughout the study period, NVPDC collected data on the physical characteristics of the NURP monitoring sites. Available site plans, construction plans, drainage plans, stormwater management plans, and development plans were compiled for all NURP monitoring sites for analysis. Drainage area boundaries were delineated on the available plans and total area, impervious cover, and effective impervious cover were planimetered. Impervious areas were designated as those areas covered by an impervious layer such as an asphalt road or rooftop. Effective impervious areas were those areas directly connected to an urban drainageway such as a gutter. For example, a rooftop which drained to a lawn area was excluded from the effective impervious measurements. The physical characteristics of the NURP monitoring sites are summarized in Table 1. BMP design features such as BMP storage capacity, release structure dimensions, and design operating performance data were also compiled. Table 2 summarizes the BMP characteristics of the twelve test watersheds which were included in the NURP montitoring study. The column labeled "BMP Inflow Data" lists the source of nonpoint pollution inflow data for comparison to the monitored BMP. For example, Table 2 indicates that inflow data for BMP efficiency calculations at Stratton Woods and Dufief are based on monitored inflows to the Westleigh wet pond BMP (Site IC) since direct measurement of inflows to runoff controls such as grassed swales is not possible. Likewise, for other BMP's which did not lend themselves to direct measurement of nonpoint pollution inflows, monitored inflows to BMP's draining similar land uses were compared with monitored inflows (e.g., Fairidge outflows were compared to monitored inflows to Burke Ponds and Dandridge infiltration trench outflows were compared to monitored inflows at Stedwick and Lakeridge dry ponds).

Numerous site inspections were conducted to confirm the veracity of the "as built" site plans and to check the delineation of the total drainage area as well as impervious and effective impervious areas. Based on these site inspections, NVPDC identified additional areas that contribute runoff to the monitoring stations at Dandridge and Stratton Woods. In both cases, site plans indicated that these areas drained outside the watersheds, however, site grading in the vicinity of the ridgeline was such that these areas contribute runoff to inlets tributary to the monitoring stations. At several sites, storm sewer manholes were inspected by NVPDC staff during runoff events to assess drainage conditions, to determine the potential for backwater effects in the vicinity of the monitoring stations, and to check for flows from outside the drainage area. At Stedwick, a site visit during a runoff event revealed that this high detention dry pond was not performing as designed. A leak at the base of the riser is suspected of decreasing the detention time to about 6 hours or about 25% of the design detention time of 24 hours for a medium sized runoff event.

TABLE 1

PHYSICAL CHARACTERISTICS OF NURP MONITORING SITES

MONITORING SITE	WATERSHED AREA (acres)	AVERAGE DENSITY (du/acre)	IMPERVIOUS GROUND COVER (%)	EFFECTIVE IMPERVIOUS GROUND COVER (%)	REPRESENTATIVE SLOPE (%)	WATERSHED AREA WITH SEPARATE STORM SEWERS (%)	WATERSHED AREA WITH CURB & GUTTER (%)
I. Large Lot Single Family Residential							
A. Stratton Woods	9.40	1.0	22.2	16.5	1.6	100	0
B. Dufief	11.04	2.2	18.5	11.1	8.5	100	0
C. Westleigh Inflow: Outflow:	40.9 47.9	1.2	21.2 24.2	14.0 16.1	3.7	100	83.7
II. Medium Density Single Family Residential							
A. Fairidge	18.8	2.8	34.1	21.0	4.3	100	0
B. Burke Pond Inflow: Outflow:	18.3 27.1	3.0	32.7 33.5	25.1 24.5	4.5	100	100
III. Townhouse/Garden Apartments							
A. Stedwick Inflow: Outflow:	27.4 34.4	6.1	33.8 30.5	22.1 19.2	4.7	100	79.7
B. Lakeridge Inflow: Outflow:	68.3 88.4	9.0	32.6 30.7	27.2 24.7	7.9	100	68.3
C. Dandridge	2.46	16.0	54.5	33.6	3.6	100	100
IV. Office							
A. Rockville Center	4.2	N/A	69.5	69.5	2.6	100	74.3
V. Industrial							
A. Bulk Mail Center Inflow: Outflow:	19.0 20.1	N/A N/A	83.0 78.5	83.0 78.5	*	100	*
VI. Shopping Centers							
A. Burke Village Shopping Center	4.5	N/A	79.2	79.2	1.6	100	82.0
B. Fair Oaks	54.7	N/A	90.0	90.0	*	*	*

*not determined

TABLE 2

BMP CHARACTERISTICS OF NURP MONITORING SITES

MONITORING SITE	BMP TYPE	STORAGE (cu.ft.)	OTHER	BMP INFLOW DATA	% BMP COVERAGE
I. Large-Lot Single Family Residential					
A. Stratton Woods	Grassed Swale	----	Mean Swale 260 ft. Mean Swale Slope 1.8%	IC.	100%
B. Dufief	Grassed Swale	----	Mean Swale Length 445 ft. Mean Swale Slope 5.1%	IC.	100%
C. Westleigh Inflow: Outflow:	Wet Pond	389,000	Pond Surface Area 50,000 sq. ft.	Monitor	100%
II. Medium Density Single Family Residental					
A. Fairidge	Grassed Swale	----	Mean Swale Length 423 ft. Mean Swale Slope 4.1%	IIB	89.4%
B. Burke Ponds Inflow: Outflow:	Wet Pond Wet Pond	353,000	Pond Surface Area 41,000 sq. ft.	Monitor	100%
III. Townhouse/Garden Apartments					
A. Stedwick Inflow: Outflow:	Dry Pond	38,000 (NPS)	5.5' 36" Riser 1/2" Perforations	Monitor	100%
B. Lakeridge Inflow: Outflow:	Dry Pond	210,000 (10 yr. 2 hr.)	7.5' Riser	Monitor	100%
C. Dandridge	Infiltration Pits	4060 (Void Space)	Perforated 6" Tile Drains	III A, B	47.6%
IV. Office					
A. Rockville City Center	Porous Pavement	27,400 (void space)	Perforated 6" Tile Drains	III A, B.	91.1%
V. Industrial					
A. Bulk Mail Center Inflow: Outflow:	Dry Pond	68,000 (NPS)	1.5' 8' Diam. Riser 1" Perforations	Monitor	100%
VI. Shopping Center					
A. Burke Village Shopping Center	Infiltration Pits	11,240 (void space)	-------	Wetfall	58.8%
B. Fair Oaks	Wet Pond	12,250	-------	-------	100%

The Soil Conservation Service (SCS) Hydrologic Soil Group classifications are used to describe soils at each site. The general characteristics of each hydrologic soil group is given below:

Hydrologic Soil Group	General Characteristics
A	Soils having high infiltration rates even when thoroughly wetted, consisting chiefly of deep, well-drained to excessively drained sands or gravels, or both. These soils have a high rate of water transmission and would result in low runoff potential.
B	Soils having moderate infiltration rates when thoroughly wetted, consisting chiefly of moderately deep to deep, moderately well-drained to well-drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission and a moderate runoff potential.
C	Soils having a slow infiltration rate when thoroughly wetted, consisting chiefly of (1) soils with a layer that impedes the downward movement of water or (2) soils with moderately fine to fine texture and slow infiltration rate. These soils have a slow rate of water transmission and a high runoff potential.
D	Soils having very slow infiltration rates when thoroughly wetted, consisting chiefly of (1) clay soils with a high swelling potential, (2) soils with a high permanent water table, (3) soils with claypan or clay layer near the surface, and (4) shallow soils over nearly impervious materials. These soils have a very slow rate of water transmission and a very high runoff potential.

The soils characteristics of the twelve BMP test watersheds are summarized in Table 3. At the low density residential sites, which are characterized by a relatively high percentage of effective pervious ground cover, soils cover a range of hydrologic soils groups, particularly at Stratton Woods where groups B, C, and D are present. In terms of soils texture, silt loam soils predominate at nine of the twelve sites. At Stratton Woods, fine sandy loams and loams are found over 70% of the drainage area. At the Lakeridge inflow and outflow stations, loamy sediments, sandy loam, and gravelly loams predominate. While soils characteristics at the highly impervious sites have less bearing on uncontrolled runoff water quality, they can affect the functioning of infiltration type BMP controls. For example, at Burke Village Center, Worsham silt loam soils of hydrologic soil group D cover 80% of the site and may inhibit infiltration into the soil from the gravel trenches located on the side and in front of the shopping center parking lot.

TABLE 3

SOILS CHARACTERISTICS AT NURP MONITORING SITES

MONITORING SITE	EFFECTIVE PERVIOUS GROUND COVER (%)	HYDROLOGIC SOIL GROUP A	HYDROLOGIC SOIL GROUP B	HYDROLOGIC SOIL GROUP C	HYDROLOGIC SOIL GROUP D	SOIL TEXTURE	PREDOMINANT SOIL SERIES	SOIL ERODIBILITY FACTOR 'K' (FROM USLE)
I. Large Lot Single Family Residential								
A. Stratton Woods	83.5	---	30%	41%	29%	Sandy Loam/Silt Loam-Loam	Brecknock/Penn/Croton	0.32/0.32/0.43
B. Dufief	88.9	---	100%	---	---	Silt Loam	Glenelg	0.34
C. Westleigh Inflow:	86.0	---	85%	15%	---	Silt Loam	Glenelg,Manor/Elioak	0.36/0.32
Outflow:	83.9	---	89%	11%	---	Silt Loam	Glenelg,Manor/Elioak	0.36/0.32
II. Medium Density Single Family Residential								
A. Fairidge	79.0	---	100%	---	---	Silt Loam	Glenelg/Manor	0.38
B. Burke Ponds Inflow:	74.9	---	78%	22%	---	Silt Loam	Glenelg/Glenville	0.34/0.32
Outflow:	75.5	---	82%	18%	---	Silt Loam	Glenelg/Glenville	0.34/0.32
III. Townhouse/Garden Apartments								
A. Stedwick Inflow:	77.9	---	100%	---	---	Silt Loam	Manor, Glenelg	0.40
Outflow:	80.8	---	100%	---	---	Silt Loam	Manor, Glenelg	0.41
B. Lakeridge Inflow:	72.8	---	67%	33%	---	Loamy Sediments	Sediments,Louisburg/ Beltsville	0.39
Outflow:	75.3	---	71%	29%	---	Sandy Loam/Gravelly Loam	Sediments,Louisburg/ Beltsville	0.31
C. Dandridge	66.4	---	100%	---	---	Silt Loam	Glenelg	0.32
IV. Office								
A. Rockville City Center	30.5	---	100%	---	---	Silt Loam	Glenelg	0.43
V. Industrial								
A. Bulk Mail Center								
Inflow:	17.0	---	100%	---	---	Sandy Loam	*	*
Outflow:	21.5	---						
VI. Shopping Center								
A. Burke Village Shopping Center	30.8	---	20%[1]	---	80%	Silt Loam	Glenelg/Worsham	0.32/0.43
B. Fair Oaks	10.0	---	*		*	*	*	*

---

*not determined

[1] Pervious Area is 100% Group B

Water Quality and Hydrometeorologic Data

The complete dataset covering the entire NURP monitoring period was received from VPI&SU in early May 1982. A computer based data management system which relied on the Statistical Analysis System (SAS) package was developed by NVPDC to thoroughly screen the raw data and to perform statistical analyses.

To screen the pollutant concentration data for coding or laboratory errors, SAS software was developed to check the sum of the nitrogen and phosphorus fractions against the total N and total P concentrations. Pollutant concentrations which were inconsistent or which exceeded a specified maximum level were flagged. For the phosphorus forms, 1.0 mg/l was selected as the maximum level, 5.0 mg/l was used for the nitrogen forms. Data which was not corrected or reverified by VPI&SU was deleted from analysis.

To compute total runoff volumes for monitored runoff events, software was developed to perform a trapezoidal rule integration of the VPI&SU flow dataset (i.e., the measured time series of instantaneous flow rate with an average interval of approximately 5-10 minutes). The trapezoidal rule integration technique uses the average flow rate between any two successive instantaneous flow measurements to derive a flow volume for each time interval. The sum of the flow volumes for each time interval during a storm event yields an approximation of the total runoff volume. Runoff hydrographs were integrated between the first and last sample times for loading calculations. For watersheds where both inflows and outflows were measured, software was developed to check for timing, duration, and total volume discrepancies between the inflow and outflow stations. As a check on runoff measurements in each test watershed, total observed runoff volumes were compared to rainfall measurements at onsite gages and/or nearby raingages. By adjusting rainfall volumes with a runoff coefficient based on the test watershed imperviousness, an estimate of total runoff volume was derived and compared with measured runoff for each storm. These analyses led to drainage area revisions at Dandridge and Stratton Woods, as previously discussed. Coding errors were detected by this method at other sites.

Runoff Data Summaries

The total number of storm events monitored at each station and the dates of the first and last event are summarized on Table 4. A total of 583 station-storms were monitored between July 1980 and December 1981. A listing of runoff pollutant concentrations and corresponding average flow rates (cfs) recorded for each station-storm for the complete monitoring period are presented in Appendices A and B. Plant nutrient data is summarized in Appendix A and the heavy metal data in Appendix B. Concentrations are in units of mg/l for the plant nutrient data and ug/l for the heavy metal data.

TABLE 4

SUMMARY OF FIRST, LAST, AND NUMBER OF EVENTS MONITORED AT NURP STATIONS

MONITORING SITE	DATE OF FIRST STORM MONITORED	DATE OF LAST STORM MONITORED	TOTAL NUMBER OF STORMS
Stratton Woods	10/25/80	10/26/81	32
Dufief	2/8/81	10/26/81	8
Westleigh Inflow:	12/9/80	12/1/81	41
Outflow:	8/15/80	12/1/81	45
Fairidge	10/2/80	12/1/81	50
Burke Ponds Inflow:	11/4/80	12/1/81	60
Outflow:	11/24/80	10/26/81	33
Stedwick Inflow:	10/18/80	12/23/81	47
Outflow:	10/25/80	12/23/81	33
Lakeridge Inflow:	7/22/80	9/3/81	49
Outflow:	8/1/80	8/3/81	41
Dandridge	9/18/80	12/15/81	58
Rockville City Center	2/20/81	11/6/81	35
Burke Village Shopping Center	11/27/80	12/4/81	51
Fair Oaks	---	---	0
			583

Precipitation Data Summaries

Due to malfunctions of the raingage accumulators at many of the NURP monitoring sites, there are extensive gaps in the onsite rainfall records. Data was obtained from nearby NWS gages to seasonally characterize the monitoring period as relatively wet or dry. In Table 5, monthly precipitation volumes for 1980-1981 are compared with corresponding mean monthly volumes for the period of record. Although during the summer (June-August) of 1980, monthly precipitation totals were 15%-39% below the long term average, precipitation during the summer of 1981 was almost average at 1%-8% below normal. The fall periods (September-November) of both 1980 and 1981 were relatively dry with precipitation at 12%-25% below normal and 32%-42% below normal, respectively. The winter period (December-January) was extremely dry, monthly precipitation totals were 46%-54% below normal. While the NURP monitoring period as a whole can be characterized as relatively dry, several months, notably February, July, and October 1981, were wetter than normal. Runoff data from the NURP monitoring sites should therefore be representative of a variety of meteorologic conditions.

III. VERIFICATION AND REFINEMENT OF LAND USE-NONPOINT POLLUTION RELATIONSHIPS FOR THE METROPOLITAN REGION

One of the major objectives of the NURP study is to compare the NURP land use/nonpoint pollution relationships with relationships developed from the 208 field study (1) which was conducted in 21 Northern Virginia watersheds between June 1976 and May 1977. The twelve month monitoring period of the 208 study was characterized by one season which was relatively wet and three seasons which were relatively dry. The 208 monitoring effort was limited to two major basins, the Occoquan River Basin and the Four Mile Run Watershed. By comparing the NURP field study monitoring data to the 208 dataset, the transferability of the 208 relationships in applications to Maryland and District of Columbia watersheds can be tested and the influence of different hydrometeorologic conditions can be assessed.

Uncontrolled Runoff Comparisons

In order to compare NURP monitoring data with data from the 208 field study, stations within the same land use category were pooled for each study and summary statistics were generated. A summary of the stations considered in each land use is presented in Table 6. Since a major objective of the NURP versus 208 analyses was to compare uncontrolled nonpoint pollution loadings, only the inflow stations to the four detention basins were included. The Rockville City Center station was grouped in the shopping center category to represent a general commercial land use. NURP monitoring stations which were drained by volume control BMP's were included in the comparisons with the 208 dataset. These sites include the infiltration pit BMP's at Dandridge and Burke Village Center and the porous pavement BMP at Rockville City Center.

TABLE 5

NWS AIRPORT GAGE MONTHLY PRECIPITATION SUMMARIES FOR NURP MONITORING PERIOD

		NATIONAL AIRPORT (DC)		DULLES AIRPORT (VA)		BALT.-WASH. INT'L (MD)	
MONTH	# OF EVENTS MONITORED	PRECIP. (inches)	DEPT. FROM NORMAL (%)	PRECIP. (inches)	DEPT. FROM NORMAL (%)	PRECIP. (inches)	DEPT. FROM NORMAL (%)
January (1980)		2.85	+1	2.95	-5	2.58	-11
February		1.16	-54	1.00	-62	1.05	-63
March		5.04	+50	4.82	+50	5.46	+48
April		3.28	+18	3.64	+34	4.24	+38
May		2.64	-31	3.86	+5	3.58	-1
June		1.68	-50	1.89	-59	3.04	-19
July[a]	3	3.86	-6	4.41	+28	3.25	-20
August	10	1.11	-67	1.67	-61	4.00	-5
September	3	1.90	-44	2.70	-29	1.00	-68
October	12	2.59	-13	2.77	-16	3.08	+10
November	36	2.56	-12	3.42	+13	2.72	-13
December	12	0.65	-79	0.68	-81	0.70	-79
January (1981)	2	0.38	-86	0.40	-87	0.49	-83
February	56	2.82	+15	4.10	+46	2.93	+4
March	22	1.49	-55	0.99	-72	1.14	-69
April	71	2.63	-8	3.05	+3	2.04	-34
May	89	3.42	-7	4.36	+18	3.63	+1
June	75	2.55	-27	3.86	+7	5.40	+43
July	51	5.69	+38	4.05	-2	4.59	+13
August	48	3.02	-35	3.55	-16	1.93	-56
September	29	1.94	-37	2.07	-37	2.89	-7
October	43	3.64	+37	3.00	+9	2.57	-9
November	6	0.29	-90	0.24	-92	0.31	-90
December[b]	15	2.80	-8	2.46	-29	3.30	+1

---

[a] Beginning of NURP monitoring period

[b] End of NURP monitoring period

TABLE 6

MONITORING STATIONS AND NUMBER OF STORMS USED FOR NURP VS. 208 COMPARISONS

Land Use	Monitoring Study	Station	Number of Storms
Large Lot Single Family Residential	NURP	Dufief	8
		Stratton Woods	31
		Westleigh BMP Inflow	41
	208	Colchester Hunt	6
		Stonewall Road	12
Medium Density Single Family Residential	NURP	Fairidge	50
		Burke Ponds BMP Inflow	60
	208	Chalet Woods	8
		Valleywood	9
		Allencrest	7
Townhouse/ Garden Apartment	NURP	Stedwick BMP Inflow	46
		Lake Ridge BMP Inflow	39
		Dandridge	56
	208	Meadows	9
		Irongate	16
		London Towne	14
		Park Fairfax	18
Shopping Center Commercial	NURP	Burke Village Centre	50
		Rockville City Center	35
	208	Korvettes Shopping Center	10
		Manassas Mall	16
		Parkington Mall	14
High-Rise Residential	208	Southern Towers	7
		Madison	4
		Cavalier Club	4
All Landuses Pooled	NURP	All NURP Stations	416
	208	All 208 Stations	154

The number of storms which were used for the NURP vs. 208 dataset comparisons is shown in Table 6. A number of NURP station-storms had to be dropped due to problems such as missing water quality data on runoff sampled during "first flush" periods at the start of a runoff event. In cases where NURP storms occurred within 4 hours of each other, the monitoring data was combined to produce a single storm event. In all, the NURP study dataset includes 416 station-storms and the 208 study dataset, 154 station-storms.

It is important to note that the 208 and NURP monitoring studies employed two different sampling methods, both of which can give excellent storm event loading approximations. All 208 storms were monitored by the sequential discrete sampling technique. The NURP study employed the flow composite sampling technique for all sites except Lakeridge. A brief description of each method is given below.

The sequential discrete sampling method (3) involves the collection of discrete samples at points along the storm runoff hydrograph. Following laboratory analyses of the individual samples, an instantaneous pollutant loading rate curve (i.e, a 'loadograph') can be generated. The area under the loading rate curve gives a total storm load estimate. While the sequential discrete sampling method greatly increases analytical costs, it does permit the investigator to determine the morphology of the pollutant loading rate curve.

Flow weighted composite sampling involves pumping of aliquots of sample into a single collection container. The sampler is programmed to activate after preselected equal increments of flow volume. The analysis of the composited sample collected after a runoff event gives an excellent estimation of the total runoff pollutant load if the sampling time intervals are small. This method does not, however, lend itself to a determination of the shape or timing of the pollutant loading rate curve.

Runoff Event Mean Concentration Comparisons

Tables 7 through 9 summarize NURP and 208 means, medians, and the coefficient of variation for runoff volumes (expressed in units of "inches" so that watersheds of different drainage areas could be aggregated by land use) and for the event mean concentrations of eleven selected constituents. The coefficient of variation is equal to the standard deviation divided by the mean. This unitless measure is used to describe the amount of variation in a population. In cases where sequential discrete sampling techniques were used (i.e., all 208 station-storms), the event mean concentration was computed from the total storm event load divided by the total runoff volume. In cases where flow composite sampling techniques were used (i.e., most of the NURP station-storms) the event mean concentration was the same as the reported mean concentration. Based on a review of cumulative probability plots and statistics on normality tests which are described below, all constituents were assumed to be lognormally (base e) distributed. The standard log transforms for a lognormal distribution were used to calculate the mean and median values presented in Tables 7 through 9.

TABLE 7

COMPARISON OF NURP AND 208 RUNOFF STATISTICS (LOGNORMAL DISTRIBUTION)
EVENT MEAN CONCENTRATIONS

CONSTITUENT	LARGE LOT SINGLE FAMILY[1]		MEDIUM DENSITY SINGLE FAMILY[2]		TOWNHOUSE GARDEN APT.[3]		SHOPPING CENTER		HIGH RISE RESIDENTIAL	
	NURP	208	NURP	208	NURP	208	NURP	208	NURP	208
RUNOFF (inches)										
N	59	13	101	21	120	45	85	40	--	15
Median	0.12	0.09	0.15	0.10	0.14	0.11	0.59	0.15	--	0.09
Mean	0.19	0.12	0.24	0.14	0.23	0.20	1.53	0.30	--	0.52
Coeff. of Variation	1.10	0.82	1.26	1.03	1.36	1.54	2.39	1.69	--	5.57
TSS (mg/L)										
N	59	13	96	21	118	45	81	40	--	15
Median	41.0	155.6	12.9	67.6	32.8	106.3	8.7	109.2	--	33.8
Mean	61.5	306.1	23.5	108.3	65.6	148.7	32.2	164.4	--	41.7
Coeff. of Variation	1.12	1.69	1.52	1.25	1.73	0.98	3.58	1.13	--	0.72
TP (mg/L)										
N	53	13	96	21	118	45	84	40	--	15
Median	0.31	0.45	0.24	0.54	0.35	0.43	0.10	0.32	--	0.17
Mean	0.37	0.52	0.31	0.63	0.43	0.50	0.15	0.39	--	0.19
Coeff. of Variation	0.61	0.59	0.84	0.64	0.72	0.57	1.07	0.65	--	0.37
PO_4 (mg/L)										
N	55	13	96	21	113	45	70	37	--	15
Median	0.16	0.13	0.11	0.17	0.14	0.08	0.04	0.01	--	0.03
Mean	0.20	0.22	0.18	0.25	0.26	0.14	0.07	0.04	--	0.04
Coeff. of Variation	0.82	1.39	1.27	1.08	1.51	1.39	1.43	2.89	--	0.90

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[1] Runoff Interval > 0.03"
[2] Runoff Interval > 0.02"
[3] Runoff Interval > 0.025"

TABLE 8

COMPARISON OF NURP AND 208 RUNOFF STATISTICS (LOGNORMAL DISTRIBUTION)
EVENT MEAN CONCENTRATIONS

CONSTITUENT	LARGE LOT SINGLE FAMILY[1]		MEDIUM DENSITY SINGLE FAMILY[2]		TOWNHOUSE GARDEN APT.[3]		SHOPPING CENTER		HIGH RISE RESIDENTIAL	
	NURP	208	NURP	208	NURP	208	NURP	208	NURP	208
TN (mg/L)										
N	53	13	94	21	118	45	78	40	--	15
Median	2.10	2.87	2.44	3.27	2.40	2.67	2.06	3.03	--	1.41
Mean	2.24	2.97	2.69	3.73	2.64	3.06	2.20	3.53	--	1.57
Coeff. of Variation	0.37	0.26	0.45	0.55	0.45	0.56	0.38	0.60	--	0.49
$NO_2 + NO_3$ (mg/L)										
N	59	13	99	21	120	45	80	40	--	15
Median	0.41	0.46	0.72	0.55	0.70	0.51	1.22	0.65	--	0.38
Mean	0.49	0.54	0.86	0.59	0.80	0.60	1.38	0.85	--	0.54
Coeff. of Variation	0.66	0.61	0.66	0.42	0.57	0.62	0.52	0.85	--	1.01
NH_3 (mg/L)										
N	59	13	99	21	119	45	83	40	--	15
Median	0.31	0.22	0.31	0.24	0.34	0.12	0.08	0.17	--	0.12
Mean	0.42	0.32	0.46	0.32	0.48	0.16	0.10	0.27	--	0.15
Coeff. of Variation	0.87	1.05	1.10	0.89	0.97	0.98	0.81	1.31	--	0.72
TKN (mg/L)										
N	53	13	96	21	118	45	83	40	--	15
Median	1.63	2.34	1.64	2.63	1.62	2.08	0.74	2.27	--	0.99
Mean	1.79	2.45	1.88	3.14	1.84	2.46	0.82	2.68	--	1.08
Coeff. of Variation	~~0.45~~	0.31	0.57	0.65	0.53	0.63	0.50	0.63	--	0.43

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[1] Runoff Interval > 0.03"
[2] Runoff Interval > 0.02"
[3] Runoff Interval > 0.025"

TABLE 9

COMPARISON OF NURP AND 208 RUNOFF STATISTICS (LOGNORMAL DISTRIBUTION) EVENT MEAN CONCENTRATIONS

CONSTITUENT	LARGE LOT SINGLE FAMILY[1]		MEDIUM DENSITY SINGLE FAMILY[2]		TOWNHOUSE GARDEN APT.[3]		SHOPPING CENTER		HIGH RISE RESIDENTIAL	
	NURP	208	NURP	208	NURP	208	NURP	208	NURP	208
COD (mg/L)										
N	57	13	99	21	116	44	83	39	--	15
Median	45.6	100.8	37.5	78.7	43.8	88.3	24.2	127.3	--	55.7
Mean	48.3	108.1	44.0	101.9	49.5	105.3	30.4	177.1	--	67.3
Coeff. of Variation	0.48	0.39	0.61	0.82	0.53	0.65	0.76	0.97	--	0.68
EPb (ug/L)										
N	3	11	3	21	21	45	5	38	--	15
Median	178	118	171	207	151	334	129	628	--	156
Mean	181	350	198	293	162	592	130	102	--	191
Coeff. of Variation	0.19	2.80	0.59	1.01	0.38	1.47	0.17	1.28	--	0.71
EZN (ug/L)										
N	50	9	79	21	110	45	56	38	--	15
Median	61	118	57	148	74	148	52	350	--	118
Mean	77	196	68	201	88	184	69	419	--	140
Coeff. of Variation	0.76	1.33	0.67	0.91	0.66	0.75	0.88	0.66	--	0.64
ECu (ug/L)										
N	10	9	19	19	27	40	21	37	--	14
Median	26	12	26	6	29	22	30	21	--	17
Mean	27	17	28	24	30	261	32	38	--	17
Coeff. of Variation	0.29	1.01	0.46	4.14	0.35	12.07	0.33	1.50	--	1.26

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[1] Runoff Interval > 0.03"
[2] Runoff Interval > 0.02"
[3] Runoff Interval > 0.025"

"Box and whisker" plots were also developed with the runoff volumes and the event mean concentrations for each urban land use category of the NURP and the 208 datasets. The important features of a box and whisker plot are shown in Figure 1. The box is composed of three horizontal lines which represent the 25th (i.e., lower quartile), the 50th (i.e., the median), and the 75th percentile (i.e., the upper quartile) of the dataset. The vertical whiskers illustrate the relationship of any extreme values to the remainder of the dataset. Within a given "box and whisker" plot the median is the measure of central tendency and the departure of the 25th and 75th percentile lines from the median provides an indication of skewness. By placing box and whisker plots from different datasets side by side, quick visual statistical comparisons can be made. For example, comparisons of the locations of the medians provide an indication of significant differences in population, while the lengths of the boxes associated with each population may be compared to provide an indication of differences in variance. The degree of symmetry about the medians may be compared to provide an indication of differences in distribution.

The one-sided Kolmogorov-Smirnov (K-S) test (4) was used to assess the adequacy of the lognormal distribution to characterize all the 208 and the NURP datasets. The one-sided K-S test concentrates on the deviations between the hypothetical cumulative distribution function (e.g., for a normal distribution) and the observed cumulative histogram. The test statistic (D_{max}) is the largest of the absolute values of the differences between the hypothesized cumulative distribution function and the observed histogram evaluated at the observed values in the sample. Since the only parameter for the K-S test is the sample size (n), it is a distribution free or non-parametric test. The critical value (c) can be computed and a hypothesis test may be performed where:

H_o: Distribution is normal

H_1: Distribution is other than normal.

The operating rule is:

Reject H_o if $D_{max} \geq c$ (e.g., probability is less than 0.05).
Accept H_o if $D_{max} \leq c$ (e.g., probability is greater than 0.05).

When H_o is not rejected, evidence exists that the observed distribution is not significantly different from the normal distribution.

Urban runoff data tends to be highly skewed towards the minor runoff events, therefore many constituents did not initially pass the one-sided K-S test for normality. Since similar distributions are required to ensure meaningful statistical comparisons, runoff thresholds were developed to delete minor runoff events from both the NURP and the 208 datasets. The establishment of the cutoff for minor events was based on iterative analyses of cumulative probability plots followed by reapplication of the one-sided

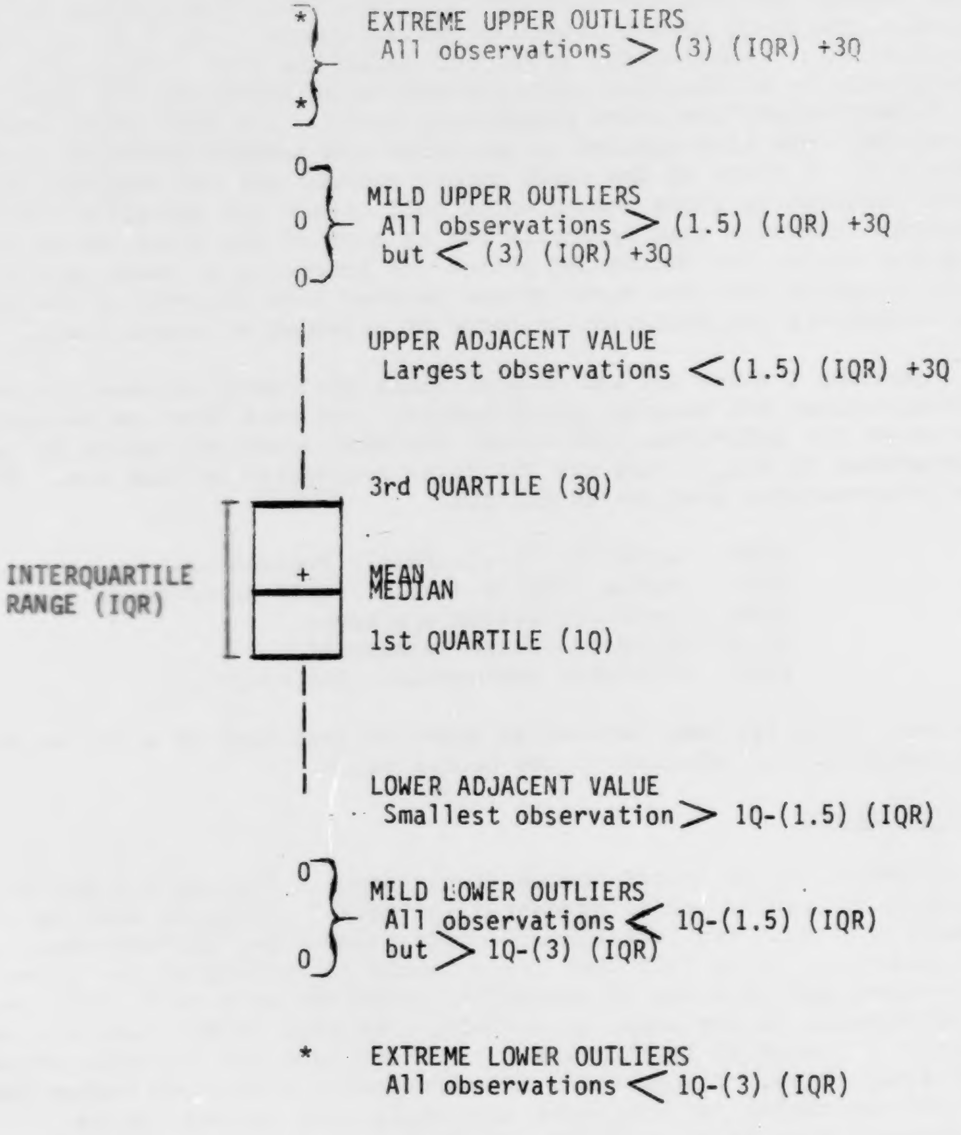
EXTREME UPPER OUTLIERS
All observations > (3) (IQR) +3Q
MILD UPPER OUTLIERS
All observations > (1.5) (IQR) +3Q
but < (3) (IQR) +3Q
UPPER ADJACENT VALUE
Largest observations < (1.5) (IQR) +3Q
3rd QUARTILE (3Q)
INTERQUARTILE RANGE (IQR)
MEAN
MEDIAN
1st QUARTILE (1Q)
LOWER ADJACENT VALUE
Smallest observation > 1Q-(1.5) (IQR)
MILD LOWER OUTLIERS
All observations < 1Q-(1.5) (IQR)
but > 1Q-(3) (IQR)
EXTREME LOWER OUTLIERS
All observations < 1Q-(3) (IQR)

Figure 1. Configuration of a box and whisker plot

K-S test. The level of significance statistics and the final runoff thresholds selected are shown in Table 10. Based on a 0.05 probability cutoff for the 95% confidence interval, the level of significance statistics in Table 10 indicate the high probability that the constituents in both the NURP and the 208 land use datasets are lognormally distributed (e.g., constituents which have probability values greater than 0.05 are normally distributed). Constituents which fell below the 0.05 significance level (designated by an asterisk) were assumed to be approximately lognormal based on inspection of cumulative probability plots. The same storm runoff volume thresholds were also applied to the means and medians presented in Tables 7 through 9. A check of the total runoff volumes and the nonpoint pollution loads produced by storm events which fall within the specified runoff interval indicates that typically 90% or more of the total volume or load produced during the monitoring period was generated by these storms. This check suggests that the minor storms deleted from the NURP or 208 datasets are relatively insignificant in terms of seasonal or annual loads.

Appendix C shows box and whisker plots for runoff volumes and event mean concentrations for selected constituents. For each land use category, plots are shown for individual NURP sites, the NURP sites aggregated by land use (designated by ALL__), and the 208 sites aggregated by land use. The land use abbreviations used are as follows:

LLSF: Large Lot Single Family Residential
MDSF: Medium Density Single Family Residential
THGA: Townhouse/Garden Apartment
SHPC: Shopping Center/Commercial
HIRI: High-Rise Residential (208 only)

The mean value for each dataset is shown on each plot by a "+" to provide an indication of its relation to the median value.

Runoff Volumes

A comparison of runoff volume plots shown in Figures C-2 and C-3 and of the mean and median values presented in Table 7 indicates that the NURP dataset typically exhibits higher runoff volumes per station-storm than the 208 datasets. It is felt that these runoff relationships are in part due to more widespread coverage of monitoring sites for each storm event and also to differences in the sampling methodologies used rather than of a wetter monitoring period or significantly different land use characteristics of the NURP study sties. A comparison of meteorologic conditions during the NURP and 208 monitoring periods shows that while both periods can be characterized as relatively dry, rainfall exceeded the normal averages during two or three months of both periods. In general, meteorologic conditions, in terms of monthly precipitation volumes, were quite similar during the two periods. A comparison of the physical features of the NURP and 208 sites indicates that, with the exception of the mean effective imperviousness for the large-lot single family classification which is approximately 25% higher for the NURP study areas, the NURP sites exhibit

TABLE 10
ONE-SIDED K-S STATISTICS FOR LOGNORMAL DISTRIBUTION
NURP AND 208 DATASETS (EVENT MEAN CONCENTRATIONS)

CONSTITUENT	LEVEL OF SIGNIFICANCE LARGE LOT SINGLE FAMILY[1] NURP	 208	 MEDIUM DENSITY SINGLE FAMILY[2] NURP	 208	 TOWNHOUSE GARDEN APT.[3] NURP	 208	 SHOPPING CENTER NURP	 208	 LAND USES[4] POOLED NURP	 208	 HIGH RISE 208
RUNOFF (inches)	0.10 (59)	>0.20 (13)	>0.20 (101)	>0.20 (21)	>0.20 (120)	0.15 (45)	>0.20 (85)	>0.20 (40)	0.05 (365)	>0.20 (119)	>0.20 (15)
TSS (mg/l)	0.15 (59)	>0.20 (13)	>0.20 (96)	>0.20 (21)	0.20 (118)	0.20 (45)	>0.20 (81)	>0.20 (40)	0.15 (354)	>0.20 (119)	>0.20 (15)
COD (mg/L)	0.05 (57)	>0.20 (13)	0.20 (99)	>0.20 (21)	>0.20 (116)	>0.20 (44)	* (83)	0.05 (39)	0.05 (355)	>0.20 (117)	>0.20 (15)
TP (mg/L)	>0.20 (53)	>0.20 (13)	>0.20 (96)	0.15 (21)	0.10 (118)	>0.20 (45)	0.05 (84)	* (40)	* (351)	0.05 (116)	>0.20 (15)
PO_4 (mg/L)	>0.20 (55)	>0.20 (13)	>0.20 (96)	>0.20 (21)	>0.20 (113)	0.15 (45)	* (70)	0.10 (37)	* (334)	0.05 (119)	>0.20 (15)
TN (mg/L)	>0.20 (53)	0.20 (13)	>0.20 (94)	>0.20 (21)	>0.20 (118)	0.15 (45)	>0.20 (78)	>0.20 (40)	>0.20 (343)	>0.20 (119)	>0.20 (15)
$NO_2 + NO_3$ (mg/L)	0.15 (59)	>0.20 (13)	0.15 (99)	>0.20 (21)	0.15 (120)	0.05 (45)	>0.20 (80)	>0.20 (40)	0.15 (358)	* (119)	0.10 (15)
NH_3 (mg/L)	>0.20 (59)	>0.20 (13)	0.20 (99)	0.05 (21)	0.20 (119)	>0.20 (45)	>0.20 (83)	0.10 (40)	0.05 (360)	0.20 (119)	>0.20 (15)
TKN (mg/L)	>0.20 (53)	0.05 (13)	>0.20 (96)	0.10 (21)	>0.20 (118)	>0.20 (45)	>0.20 (83)	>0.20 (40)	>0.20 (350)	>0.20 (119)	>0.20 (15)
EPb (ug/L)	-- (3)	0.10 (11)	-- (3)	0.05 (21)	0.05 (21)	>0.20 (45)	>0.20 (5)	>0.20 (38)	0.05 (32)	>0.20 (115)	>0.20 (15)
EZN (ug/L)	0.15 (50)	>0.20 (9)	0.20 (79)	>0.20 (21)	0.15 (110)	>0.20 (45)	* (56)	>0.20 (38)	* (295)	>0.20 (113)	0.15 (15)
ECu (ug/L)	0.01 (10)	>0.20 (9)	* (19)	0.05 (19)	* (27)	0.15 (40)	0.05 (21)	0.15 (37)	* (77)	* (105)	0.15 (14)

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[1] RUNOFF INTERVAL > 0.03"
[2] RUNOFF INTERVAL > 0.02"
[3] RUNOFF INTERVAL > 0.025"
[4] INTERVALS APPLIED TO LLSF, MDSF & THGA

similar or lower mean effective imperviousness. Soils at the NURP sites are predominately hydrologic soil group B and should have somewhat lower runoff potential than the soils at the 208 sites which are predominately hydrologic group C. In general, the comparison of physical characteristics and soils data suggests that NURP sites should exhibit similar or lower runoff volumes than the 208 sites. With the exception of the medium density single family land use category, the median runoff volumes for the NURP and the 208 datasets were close enough so that the two datasets for each land use represent similar populations. This is statistically substantiated in a later section.

The higher runoff volumes which typically characterize the NURP dataset probably contributed to the lower event mean concentrations which are noted for many constituents at the NURP sites in comparison to the 208 sites. Higher runoff volumes would suggest that the NURP station-storms are also characterized by higher dilution potentials, particularly for major storm events at the highly impervious urban land uses where paved areas tend to be flushed during high runoff events and runoff tends to exhibit very high concentrations during the early stages of runoff (i.e., due to first-flush effects on paved surfaces) followed by relatively low concentrations during the remainder of the runoff event. The different sampling technique used in the 208 study (i.e., sequential discrete sampling) may have produced event mean concentrations which overestimate suspended loadings which tend to occur near the beginning of runoff event and which underestimate dissolved loadings which tend to occur at or after peak runoff periods (i.e., when runoff would have the highest contribution from pervious surfaces which should contribute a relatively high dissolved fraction). The probable consequences of comparing event mean concentrations determined by the 208 sequential discrete sampling mode with event mean concentration determined by the flow composite sampling mode of the NURP study is discussed in a later section.

Event Mean Concentrations

Due to the higher runoff volumes at the NURP sites and the different sampling techniques used during the two studies, it was decided that unit area loads (e.g., lbs/acre) rather than event mean concentrations would be used to compare "land use-nonpoint pollution" relationships. Land use comparisons based on event mean concentrations, however, provide many insights as to differences between the datasets. The comparisons below are based on the means/medians presented in Tables 7 through 9 and the box and whisker diagrams in Appendix C.

1. Total Suspended Solids (TSS): Median NURP concentrations are typically 10%-30% of the median 208 values for all land use classifications. Since TSS typically exhibits the most pronounced first-flush of all pollutants, it is most susceptible to dilution effects resulting from the higher runoff volumes characterizing the NURP dataset. The NURP datasets for townhouse/garden apartments and shopping center land use categories include sites with

infiltration type BMP's; therefore NURP median values for these land uses would be expected to be lower than 208 median concentrations.

2. Chemical Oxygen Demand (COD): Median NURP concentrations are all in the range of 25-50 mg/L, while 208 median values are on the order of 75-125 mg/L. These relationships suggest that the NURP dataset should be characterized by lower organic fractions of plant nutrients.

3. Phosphorus Forms: Although NURP total phosphorus (total-P) median concentrations are typically lower than 208 median values, ortho-P, which is in dissolved form, has a higher median concentration at all NURP land uses except medium density single family.

4. Nitrogen Forms: For total nitrogen (total-N), NURP median values are typically within 70-90% of 208 median values. For total kjeldahl nitrogen (TKN), NURP median values are somewhat lower than 208 medians, due to the lower organic fraction suggested by the COD plots. For ammonia-N and nitrate-N which are both dissolved fractions, NURP median concentrations are typically higher than 208 median values. The much lower total N, TKN and ammonia-N values and higher nitrate-N median values at the NURP shopping center sites can be attributed to pollutant removal and transformation (e.g., nitrification mechanisms) within the infiltration BMP's serving these sites.

5. Extractable Lead: Due to a change in analytical technique during late Spring of 1981 from flame atomic absorption (AA) spectroscopy (i.e., detection limit 100 u/gL) to furnace AA techniques (i.e., detection limits 1 ug/L), there are only a very limited number of datapoints with which to make comparisons with the 208 datasets. Since the 208 study relied on flame AA techniques, only NURP concentrations determined by the flame AA method are compared to the 208 dataset. For extractable lead, NURP median concentrations are typically quite close to 208 median values. The lower median for NURP shopping center and townhouse sites can be attributed in part to the BMP's serving these sites.

6. Zinc: NURP median values for extractable zinc are typically 40%-50% of 208 median values. The much lower extractable zinc concentration for the NURP shopping center sites may be due to removal by absorption mechanisms in the soil profile beneath the infiltration facility.

7. Copper: The NURP median values for extractable copper typically bracket or somewhat exceed the 208 median values.

Unit Area Loading Comparisons

Although the NURP dataset is typically characterized by lower event mean concentrations than the 208 dataset, the higher runoff volumes per station-storm generally result in similar loading rates (lbs/acre) per storm event. Tables 11 through 13 summarize the NURP and 208 means and medians and the coefficients of variation for runoff volumes (inches) and unit area loads (lbs/acre) for eleven selected constituents. For stations where event mean concentrations were reported, unit area loads were calculated as:

$$\text{LOAD (lbs/ac)} = (C) * (Q) * (K)/A$$

where:

C = event mean concentration (mg/L)

Q = runoff volume (ft^3)

A = drainage area (acres)

$K = 6.24 \times 10^{-5}$ ($L * lbs/ft^3 * mg$)

Since unit area loads are a function of runoff volumes, the differences in runoff volumes between the NURP and the 208 datasets described earlier are much more critical. To ensure meaningful comparisons between the NURP and 208 loading datasets, it was necessary to demonstrate first that the runoff volume datasets for a given land use category: (1) exhibit similar distributions and (2) have similar central values (e.g., mean or median). Statistical tests, presented in a later section, were used to quantitatively check the NURP and 208 runoff volume datasets for each land use category. Due to several very large events at the NURP medium density single family sites, it was necessary to apply a runoff threshold to both the NURP and 208 datasets in this category. The final threshold was obtained by inspection of cumulative probability plots and reapplication of the statistical tests. Only three of 110 station-storms were dropped from the NURP medium density single family datasets. None were dropped from the 208 dataset.

Box and whisker plots presented in Appendix D were also developed for the unit area loading datasets. Land use comparisons based on the unit area load statistics in Tables 11 through 13 and the box and whisker plots in Appendix D are presented below.

1. Total Suspended Solids: Median NURP loads are typically 30%-50% of the median 208 values. The much lower loading rates at all of the NURP large lot and medium density single family land use categories suggest that TSS loadings may have been overestimated at the 208 sites. It is felt that the sequential discrete sampling technique may have overemphasized loadings on the rising limb of the runoff hydrograph where TSS concentrations are typically highest. Another contributing factor may have been that one of the 208 study

TABLE 11

COMPARISON OF NURP AND 208 RUNOFF STATISTICS (LOGNORMAL DISTRIBUTION)
UNIT AREA LOADS

CONSTITUENT	LARGE LOT SINGLE FAMILY		MEDIUM DENSITY SINGLE FAMILY		TOWNHOUSE GARDEN APT.		SHOPPING CENTER		HIGH RISE RESIDENTIAL
	NURP	208	NURP	208	NURP	208	NURP	208	208
RUNOFF (inches)									
N	80	18	107	24	141	57	85	40	15
Median	0.07	0.05	0.11	0.08	0.096	0.071	0.23	0.15	0.09
Mean	0.17	0.11	0.21	0.13	0.22	0.17	0.47	0.30	0.52
Coeff. of Variation	2.33	1.84	1.58	1.39	2.01	2.25	1.80	1.69	5.58
TSS (lbs/ac)									
N	80	18	101	24	139	57	81	40	15
Median	0.62	1.94	0.34	1.34	0.74	1.75	0.45	3.81	0.70
Mean	2.45	6.97	0.99	2.31	2.49	5.17	8.81	8.20	4.21
Coeff. of Variation	3.81	3.45	2.77	1.40	3.22	2.79	19.5	1.91	5.91
TP (lbs/ac)									
N	73	18	101	24	137	57	84	40	15
Median	0.005	0.005	0.006	0.009	0.007	0.007	0.005	0.011	0.004
Mean	0.014	0.013	0.016	0.016	0.024	0.017	0.019	0.025	0.026
Coeff. of Variation	2.70	2.33	2.45	1.44	3.09	2.25	3.45	1.96	7.29
PO_4 (lbs/ac)									
N	75	18	101	24	131	56	70	36	15
Median	0.002	0.001	0.003	0.002	0.003	0.001	0.002	0.001	0.001
Mean	0.008	0.007	0.010	0.010	0.021	0.010	0.014	0.003	0.007
Coeff. of Variation	3.43	4.81	3.49	4.02	7.05	8.47	6.83	6.10	12.04

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[1] Runoff Interval < 0.8"

TABLE 12

COMPARISON OF NURP AND 208 RUNOFF STATISTICS (LOGNORMAL DISTRIBUTION)
UNIT AREA LOADS

CONSTITUENT	LARGE LOT SINGLE FAMILY		MEDIUM DENSITY[1] SINGLE FAMILY		TOWNHOUSE GARDEN APT.		SHOPPING CENTER		HIGH RISE RESIDENTIAL
	NURP	208	NURP	208	NURP	208	NURP	208	208
TN (lbs/ac)									
N	74	18	99	24	137	57	78	40	15
Median	0.033	0.036	0.062	0.058	0.054	0.047	0.113	0.106	0.02
Mean	0.079	0.080	0.121	0.091	0.132	0.091	0.215	0.184	0.224
Coeff. of Variation	2.18	2.01	1.70	1.23	2.24	1.66	1.62	1.43	7.72
$NO_2 + NO_3$ (lbs/ac)									
N	80	18	105	24	141	57	80	40	15
Median	0.007	0.006	0.018	0.009	0.015	0.009	0.066	0.023	0.008
Mean	0.016	0.013	0.036	0.017	0.039	0.019	0.111	0.037	0.116
Coeff. of Variation	2.03	2.17	1.71	1.57	2.32	1.82	1.36	1.31	14.4
NH_3 (lbs/ac)									
N	79	18	105	24	140	57	83	40	15
Median	0.005	0.003	0.008	0.004	0.007	0.002	0.004	0.006	0.003
Mean	0.015	0.006	0.020	0.008	0.026	0.007	0.013	0.014	0.012
Coeff. of Variation	2.75	2.14	2.38	1.80	3.46	3.62	2.96	2.16	4.49
TKN (lbs/ac)									
N	74	18	101	24	137	57	83	40	15
Median	0.025	0.029	0.041	0.047	0.036	0.036	0.039	0.079	0.021
Mean	0.067	0.067	0.088	0.074	0.093	0.072	0.097	0.149	0.139
Coeff. of Variation	2.46	2.07	1.88	1.22	2.40	1.73	2.29	1.60	6.67

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[1] Runoff Interval < 0.8"

TABLE 13

COMPARISON OF NURP AND 208 RUNOFF STATISTICS (LOGNORMAL DISTRIBUTION)
UNIT AREA LOADS

CONSTITUENT	LARGE LOT SINGLE FAMILY		MEDIUM DENSITY[1] SINGLE FAMILY		TOWNHOUSE GARDEN APT.		SHOPPING CENTER		HIGH RISE RESIDENTIAL
	NURP	208	NURP	208	NURP	208	NURP	208	208
COD (lbs/ac)									
N	76	18	104	24	136	57	83	40	15
Median	0.77	1.06	0.96	1.46	0.96	1.61	1.27	4.51	1.16
Mean	1.69	3.36	1.92	2.69	2.21	3.41	3.18	8.49	14.03
Coeff. of Variation	1.96	3.00	1.74	1.55	2.07	1.87	2.31	1.59	12.09
EPb (lbs/ac)									
N	5	14	2	24	28	57	5	38	15
Median	0.001	0.012	0.010	0.013	0.002	0.006	0.011	0.022	0.003
Mean	0.002	0.007	0.004	0.006	0.004	0.015	0.015	0.062	0.054
Coeff. of Variation	14.1	2.9	0.80	1.07	1.41	2.23	1.04	2.66	16.6
EZN (lbs/ac)									
N	69	17	82	24	130	57	56	38	15
Median	0.001	0.002	0.001	0.003	0.002	0.003	0.003	0.012	0.002
Mean	0.003	0.004	0.003	0.004	0.004	0.005	0.008	0.024	0.026
Coeff. of Variation	2.67	2.11	2.06	1.00	1.94	1.56	2.41	1.64	10.7
ECu (lbs/ac)									
N	16	12	20	20	34	52	21	37	13
Median	0.0	0.0	0.001	0.0	0.0	0.0	0.001	0.001	0.0
Mean	0.001	0.0	0.001	0.0	0.001	0.005	0.003	0.002	0.001
Coeff. of Variation	2.61	1.61	1.49	1.25	2.84	11.8	2.42	2.73	3.51

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[1] Runoff Interval < 0.8"

guidelines was to emphasize the characterization of first-flush effects. With the exception of one site, the NURP sampling program relied on an automatic flow compositing sampling technique* which placed equal emphasis on each specified unit volume of sample (e.g., the sampler may have fired every 1,000 cubic feet of runoff volume) and therefore provides a more comprehensive coverage of concentrations during a runoff event. With the flow composite sampling technique, it is less likely that a greater weight was inadvertently placed on any particular section of the runoff hydrograph.

2. Chemical Oxygen Demand (COD): Median COD loadings are only slightly lower (15%-25%) than 208 study median values for all land uses except shopping center. The box and whisker plots in Figures D-7 and D-8 show the similarities of NURP and 208 land use distributions for COD loadings. Higher suspended P loadings characterizing the 208 study may be related to the higher TSS loadings discussed above and may explain the slightly lower COD loadings of the NURP residential land uses. For the shopping center land uses, NURP median loadings are 30% of the 208 values which seem to be related to the BMP's serving the NURP sites.

3. Phosphorus Forms: Although NURP total P median loadings are quite similar to the 208 values (i.e., 55%-100% of 208 median loadings), the NURP land use categories tend to have much higher ortho-P median loadings (i.e., 150%-200% of 208 median values). Ortho-P is generally considered the most readily available form for algal growth.

4. Nitrogen Forms: For total N loadings, the NURP median values are typically quite close to the 208 median values. Median total N loadings are slightly lower for the large lot single family land use and slightly higher for medium density and townhouse land uses. For ammonia-N and nitrate, NURP median loadings are similar to 208 median for the large lot single family land uses and somewhat higher for medium density and townhouse land uses. For total kjeldahl nitrogen loadings, the NURP and 208 median values are quite similar for all residential land use categories.

5. Extractable Lead (EPb): Median EPb loadings at the NURP land uses seem to be much lower than the corresponding 208 land uses. However, the very limited amount of data (i.e., within three of the four land use categories, there are five or less datapoints for

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*At all NURP sites except Lakeridge, the sampler automatically withdraws a runoff sample at equal preselected volumes of flow. At the Lakeridge site, where sampling equipment used in the 1966-1977 208 study was installed, sequential discrete samples are automatically withdrawn by the sampler and then manually composited in the laboratory for analysis.

comparison) does does not lend much confidence to these comparisons. Lower lead loadings could be attributed to increased use of lead-free gasoline since the 208 study which was performed in 1976-1977. This may be especially true for the shopping center land use category which is characterized by high traffic levels.

6. Extractable Zinc (EZn): The NURP extractable zinc median loadings are much lower than the 208 values. From the much higher fractions of soluble zinc of the NURP land use categories discussed below, it can be inferred that the much lower median loadings for the NURP residential land uses are due in large part to the significantly lower suspended loadings.

Sequential Discrete vs. Flow Composite Sampling Methodologies

The comparisons between the NURP and 208 land use datasets bring out several apparent trends.

1. In spite of the somewhat drier meteorological conditions during the NURP monitoring period, the NURP datasets typically display higher runoff volumes.

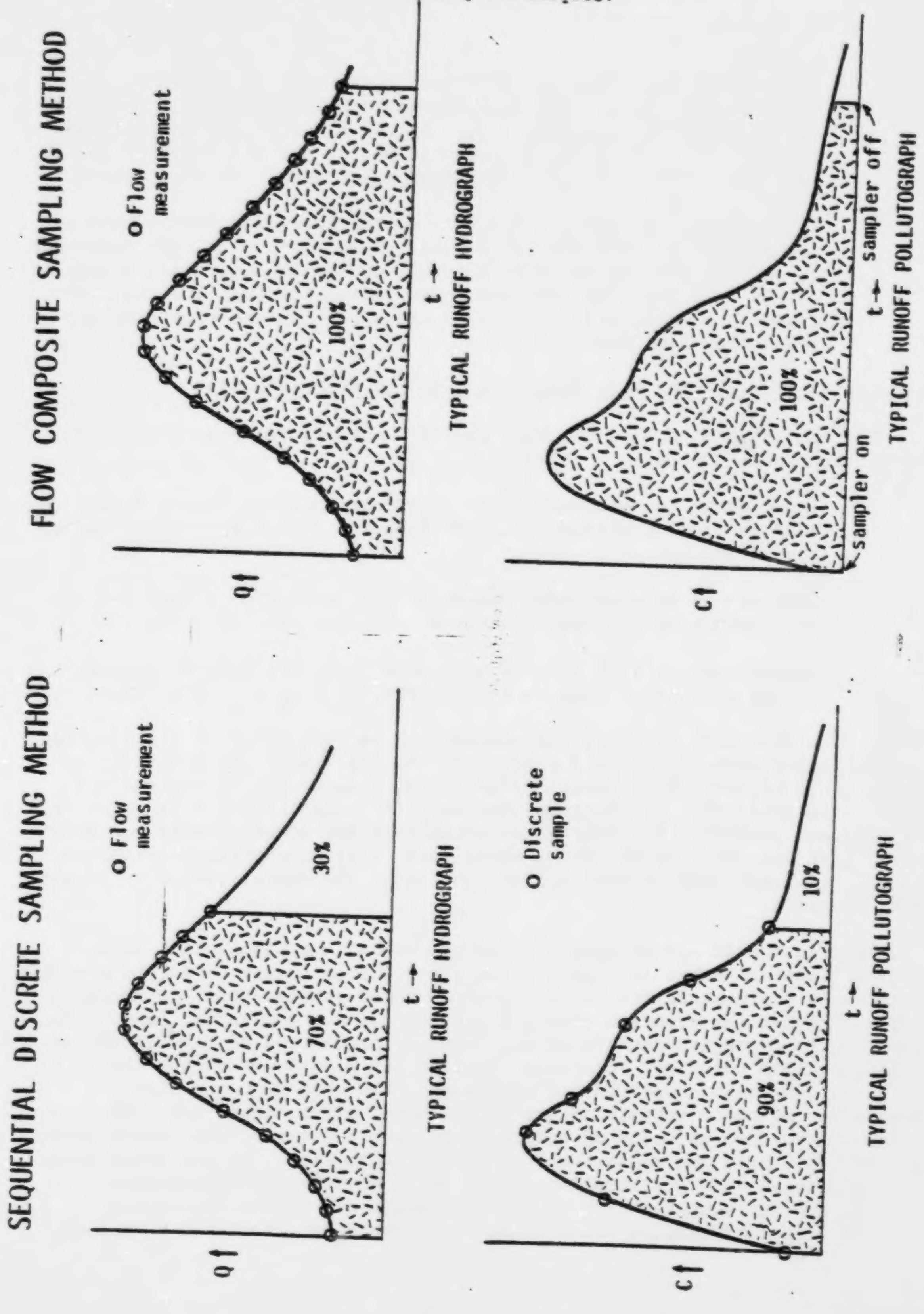
2. Comparisons of event mean concentrations show much higher 208 concentrations for many constituents (e.g., TSS, COD, TP, EZN).

3. Comparisons of NURP and 208 unit area loads are typically much closer than event mean concentrations for a given constituent.

It is felt that many of these differences can be attributed to the sampling technique and emphasis of each study. In the 208 study, characterization of first flush effects which occur on the rising limb of the hydrograph was given high priority. In addition, the samplers were limited to a total of 24 discrete samples. The NURP study emphasized BMP effectiveness for which field data was required to assess reductions in total pollutant transport (e.g., pollutant load removal due to settling); therefore, composite samples were adequate.

Typical runoff hydrographs and pollutographs (e.g., pollutant load versus time) are shown in Figure 2 for a hypothetical storm event to present a probable explanation for the differences noted between the flow composite and the sequential discrete sampling methodologies. The shaded areas under each curve are representative of the relative percentage of flow volume or pollutant load which was 'captured' by each sampling methodology. It is felt that there is a much better likelihood that data from the flow composite method is representative of the total storm volume and load because many more aliquots of sample could be drawn during the runoff event, particularly from the recession limb of the hydrograph. On the other hand, the sequential discrete sampling method may have missed a significant portion of the recession limb of the hydrograph due to the relatively limited number of samples which could be taken to be associated with flow

FIGURE 2 Comparison of Flow Composite and Sequential Discrete Sampling Techniques.



measurements. For pollutants which exhibit a significant first flush effect, however, the sequential discrete method may have done an adequate job of depicting the total pollutant transport. Figure 2 shows that comparisons of event mean concentrations (e.g., total pollutant load divided by total runoff volume) for similar storm events sampled by the sequential discrete versus flow composite methods may introduce large errors (e.g., in Figure 2, on the order of 30% in event mean concentrations), however, comparisons of total pollutant loads are quite good (e.g., in Figure 2, there is only a 10% difference in measured loads). It is evident that this scenario could explain the trends noted in the comparisons between the NURP and 208 datasets.

Dissolved and Inorganic Fractions

Pollutant fractions refer to the ratio of some fraction of a pollutant to the total pollutant concentration (e.g., total soluble P/total P). Since the volume term cancels in the ratio, event mean concentrations, and not unit area loads, may be used to calculate fractions. Table 14 summarizes the mean fractions for the NURP and the 208 land uses categories. Both volume weighted (i.e., observations weighted by runoff volume in inches) and log means (i.e., fractions were log transformed and means were calculated) are presented. Box and whisker plots, presented in Appendix E, were also developed for pollutant fractions.

1. Phosphorus Fractions: Mean soluble phosphorus fractions are considerably higher for the NURP dataset and exceed comparable 208 land uses on the order of 10-15% at the residential land uses. At the shopping center land use category the NURP fractions are about 25% greater. Mean ortho-P fractions are also considerably higher for the NURP land use datasets, ranging from 0.42 to 0.58 for all land use categories. By comparison, the mean ortho-P fractions for the 208 dataset are approximately 0.29 to 0.48 for residential categories and 0.10 to 0.16 for the shopping center category. The higher soluble and inorganic fraction of the NURP datasets, suggest higher bioavailability of phosphorus than was determined from the 208 data. Bioassays would be required, however, to confirm this (5).

2. Nitrogen Fractions: All NURP land uses exhibit soluble nitrogen fractions between 0.80 and 0.95 while 208 land uses are typically 0.60 to 0.75. The NURP dataset also exhibits a considerably higher inorganic nitrogen fraction. For the NURP residential land uses, the fraction of inorganic nitrogen is typically 0.35 to 0.50 for residential land uses and 0.65 to 0.70 for the shopping center land use category. All 208 land uses exhibit inorganic nitrogen fractions between 0.27 to 0.33.

3. Soluble Zinc Fractions: For comparable land uses, the mean soluble zinc fractions are approximately 0.70 to 0.80 for the NURP datasets and 0.35 to 0.65 for the 208 datasets.

TABLE 14

COMPARISON OF NURP AND 208 POLLUTANT FRACTIONS

	LARGE LOT SINGLE FAMILY		MEDIUM DENSITY SINGLE FAMILY		TOWNHOUSE GARDEN APT.		SHOPPING CENTER	
	NURP	208	NURP	208	NURP	208	NURP	208
FRACTION SOLUBLE-P								
N	71	18	102	24	132	57	82	40
Volume Weighted Mean	0.69	0.61	0.79	0.60	0.63	0.53	0.70	0.47
Mean*	0.67	0.56	0.74	0.52	0.62	0.53	0.68	0.43
FRACTION ORTHO-P								
N	69	18	98	24	127	56	69	37
Volume Weighted Mean	0.53	0.35	0.58	0.48	0.54	0.39	0.42	0.10
Mean*	0.51	0.35	0.55	0.42	0.54	0.29	0.43	0.16
FRACTION SOLUBLE-N								
N	72	18	102	24	136	57	75	40
Volume Weighted Mean	0.83	0.74	0.87	0.65	0.80	0.64	0.93	0.71
Mean*	0.80	0.73	0.88	0.58	0.78	0.58	0.89	0.69
FRACTION INORGANIC-N								
N	73	18	102	24	137	57	78	40
Volume Weighted Mean	0.33	0.27	0.43	0.30	0.50	0.30	0.68	0.31
Mean*	0.38	0.29	0.47	0.27	0.48	0.28	0.66	0.33
FRACTION SOLUBLE ZINC								
N	48	17	60	24	103	57	44	38
Volume Weighted Mean	0.71	0.36	0.78	0.65	0.67	0.31	0.75	0.52
Mean*	0.73	0.39	0.78	0.57	0.71	0.41	0.74	0.52

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*Lognormal Distribution Assumed

Statistical Tests of Distribution and Median/Means

The preceeding comparison of unit area loading rates based on a review of median/mean value and box and whisker plots gives a good general idea of the inherent similarities and differences between the NURP and the 208 datasets. It is also necessary to calculate statistics which quantify these results. The objective of the statistical analyses presented below is to determine whether there is a statistically significant difference between the NURP and the 208 datasets in terms of either frequency distribution or the central value (i.e., mean and/or median).

Inspection of box and whisker diagrams, cumulative probability plots and the results of the one-sided K-S test indicate that many constituents may not exhibit either normal or lognormal distributions for both the NURP and the 208 datasets. Nonparametric (or distribution free) statistical techniques have a much higher power than conventional normal statistical techniques for analyses of datasets characterized by the small sample sizes and the skewed distributions typical of water quality datasets. Both parametric (i.e., normal distribution) and nonparametric statistics were used to assess the NURP and 208 datasets.

The parametric statistics employed are the one-sided K-S test statistic for normality, which was previously described, the t-statistic on the difference between the means of the NURP and 208 dataset for a given constituent (6), and the F (folded)-statistic on the difference between the variance of the NURP and 208 datasets. The t-statistic tests for differences in the central values, assuming that both the NURP and the 208 datasets exhibit lognormal distributions (i.e., statistically different variances can be accommodated as long as the criterion of lognormality is satisfied. The F statistic uses the ratio of the variances to test the assumption that the variances are equal.

The nonparametric statistics used are briefly described below. The two-sided Kolmogorov-Smirnov analysis (7) is a test for any significant difference of one distribution from another (i.e., NURP vs. 208). The analysis is analagous to the one-sided K-S test in that it involves checking the maximum difference between the two distributions to determine if it exceeds a critical value. Since it is a broad alternative test, the two-sided K-S test has lower power for any specific alternative, such as a difference in central values. The Wilcoxon Rank Sum analysis (8) is used to compensate for this difficulty since it is designed to test for differences in median values, under the assumption that the two distributions being compared may differ only with respect to this value. The Wilcoxon Rank Sum test assigns ranks to a combined dataset (e.g., NURP and 208 datasets combined) and calculates the sum of the data ranks for each dataset (e.g., NURP ranks summed vs. 208 ranks summed). If the median value of one dataset differs significantly from the median value of the other dataset, the sum of the ranks will be higher or lower. The rank sum is normally distributed and can be compared to values in the standard normal probability table to determine how large it must be in order to be considered the result of two different populations.

Based on reviews of probability plots, lognormal distributions were assumed for the computation of the parametric statistics. In order to conclude that there is no significant difference between the NURP and the 208 datasets based upon parametric statistics, the level of significance for both one-sided K-S test (i.e., both NURP and 208) and the F-statistic should be greater than or equal to the probability cutoff for the desired confidence interval (e.g., $\alpha = 0.05$ for the 95% confidence interval).

Tables 15 through 16 summarize the parametric and nonparametric statistics for comparisons of the NURP and 208 land use runoff datasets. Comparisons are presented for (1) large lot single family; (2) medium density single family; (3) single family residential (LLSF + MDSF); (4) townhouse/garden apartment; and (5) shopping center. The entries in the "HYPOTHESIS" column indicate acceptance or rejection of the null hypothesis* based upon a 0.05 probability cutoff for the 95% confidence interval. Acceptance of the null hypothesis is based upon at least one of the following: (a) an acceptable level of significance for the Wilcoxon Rank Sum statistic, in the case of NURP and 208 datasets which pass the two-sided K-S test; (b) an acceptable level of significance for the T-statistic, in the case of NURP and 208 datasets for which the existence of normal distributions is quantified with the one-sided K-S test; or (c) an acceptable level of significance for both the Wilcoxon Rank Sum statistic and the T-statistic in the case of NURP and 208 datasets for which the existence of normal distributions is assumed rather than quantified.

Since the statistical analyses summarized in Tables 15 through 17 were performed on unit area loading rates (e.g., lbs/ac), it was necessary to first demonstrate that there was no significant difference in the runoff volume datasets. As previously described, a runoff threshold was applied to both the NURP and the 208 medium density single family runoff datasets to account for the higher runoff volumes recorded at the NURP sites.

Comparisons of NURP vs. 208 land use-nonpoint pollution relationships are presented below:

- Large-Lot Single Family: Based on the statistics summarized in Table 15, there is no significant difference between the NURP and the 208 loading datasets for all phosphorus and nitrogen forms. The higher TSS loadings at the 208 sites, which was also noted by the comparisons of medians and box and whisker plots, is confirmed by these tests. The ratio of the median loading rates shows that the NURP loading rates are approximately one third of the 208 values. The 208 datasets also show significantly higher extractable lead loading rates. This could be attributed to increased use of lead-free gasoline since the 1976-1977 monitoring study.

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*HO: NURP distribution = 208 distribution or
HO: NURP mean (median) = 208 mean (median)

TABLE 15

COMPARISON OF NURP vs. 208 LAND USE RUNOFF STATISTICS
LARGE LOT SINGLE FAMILY
UNIT AREA LOADS

CONSTITUENT	N 208	N NURP	PARAMETRIC STATISTICS[1] LEVEL OF SIGNIFICANCE ONE-SIDED K-S-TEST 208	PARAMETRIC STATISTICS[1] LEVEL OF SIGNIFICANCE ONE-SIDED K-S-TEST NURP	PARAMETRIC STATISTICS[1] LEVEL OF SIGNIFICANCE T-STATISTIC ON MEANS	PARAMETRIC STATISTICS[1] LEVEL OF SIGNIFICANCE F-STATISTIC ON VARIANCES	NONPARAMETRIC STATISTICS LEVEL OF SIGNIFICANCE TWO-SIDED K-S DISTRIBUTION TEST	NONPARAMETRIC STATISTICS LEVEL OF SIGNIFICANCE WILCOXON RANK SUM MEDIAN TEST	HYPOTHESIS SIGNIFICANTLY DIFFERENT DISTRIBUTION	HYPOTHESIS SIGNIFICANTLY DIFFERENT MEAN OR MEDIAN	HYPOTHESIS HIGHER MEAN/MEDIAN VALUE
RUNOFF (inches)	18	80	>0.20	0.10	0.46	0.61	0.74	0.48	NO	NO	---
TSS (lbs/ac)	18	80	>0.20	>0.20	*	0.92	0.05	*	NO	YES	208
COD (lbs/ac)	18	76	>0.20	>0.20	0.35	0.27	0.59	0.21	NO	NO	---
TOTAL-P (lbs/ac)	18	73	>0.20	>0.20	0.85	0.80	0.96	0.85	NO	NO	---
ORTHO-P (lbs/ac)	18	75	0.15	>0.20	0.22	0.50	0.50	0.26	NO	NO	---
TOTAL-N (lbs/ac)	18	74	>0.20	>0.20	0.82	0.90	0.81	0.82	NO	NO	---
NITRATE-N (lbs/ac)	18	80	0.05	0.15	0.50	0.80	0.19	0.32	NO	NO	---
AMMONIA-N (lbs/ac)	18	79	>0.20	0.20	0.09	0.62	0.26	0.08	NO	NO	---
TKN (lbs/ac)	18	74	>0.20	>0.20	0.61	0.74	0.63	0.61	NO	NO	---
EPB (lbs/ac)	14	5	>0.20	>0.20	*	0.21	*	*	YES	YES	208
PBF (lbs/ac)	--	--	--	--	--	--	--	--	--	--	---
EZN (lbs/ac)	17	69	>0.20	>0.20	0.11	0.65	0.20	0.11	NO	NO	---
ECU (lbs/ac)	12	16	>0.20	*	*	0.43	*	*	YES	YES	---

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[1] Assumed Lognormal Distribution
*Level of Significance is less than 0.05

TABLE 16

COMPARISON OF NURP vs. 208 LAND USE RUNOFF STATISTICS: MEDIUM DENSITY SINGLE FAMILY[1]
UNIT AREA LOADS

CONSTITUENT	N	N	PARAMETRIC STATISTICS[2] LEVEL OF SIGNIFICANCE				NONPARAMETRIC STATISTICS LEVEL OF SIGNIFICANCE		HYPOTHESIS		
	208	NURP	ONE-SIDED K-S-TEST		T-STATISTIC ON MEANS	F-STATISTIC ON VARIANCES	TWO-SIDED K-S DISTRIBUTION TEST	WILCOXON RANK SUM MEDIAN TEST	SIGNIFICANTLY DIFFERENT DISTRIBUTION	SIGNIFICANTLY DIFFERENT MEAN OR MEDIAN	HIGHER MEAN/MEDIAN VALUE
			208	NURP							
RUNOFF (inches)	24	107	>0.20	0.10	0.09	0.60	0.06	0.06	NO	NO	---
TSS (lbs/ac)	24	101	>0.20	0.15	*	0.06	*	*	NO	YES	208
COD (lbs/ac)	24	104	>0.20	>0.20	0.12	0.75	0.51	0.24	NO	NO	---
TOTAL-P (lbs/ac)	24	101	>0.20	*	0.16	0.13	0.24	0.11	NO	NO	---
ORTHO-P (lbs/ac)	24	101	0.10	0.15	0.61	0.71	0.98	0.76	NO	NO	---
TOTAL-N (lbs/ac)	24	99	>0.20	0.20	0.80	0.28	0.96	0.75	NO	NO	---
NITRATE-N (lbs/ac)	24	105	>0.20	0.10	*	0.82	*	*	NO	YES	NURP
AMMONIA-N (lbs/ac)	24	105	>0.20	0.10	*	0.47	*	*	NO	YES	NURP
TKN (lbs/ac)	24	101	>0.20	>0.20	0.63	0.16	0.71	0.64	NO	NO	---
EBP (lbs/ac)	24	2	>0.20	--	0.15	1.0	*	*	--	--	---
PBP (lbs/ac)	--	--	--	--	--	--	--	--	--	--	---
EIN (lbs/ac)	24	82	>0.20	>0.20	*	*	*	*	NO	YES	NURP
ECU (lbs/ac)	20	20	>0.20	0.10	*	0.65	*	*	NO	YES	NURP

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[1] Runoff Threshold < 0.8"

[2] Assumed Lognormal Distribution

*Level of Significance is less than 0.05

TABLE 17

COMPARISON OF NURP vs. 208 LAND USE RUNOFF STATISTICS: SINGLE FAMILY[1,2] UNIT AREA LOADS

CONSTITUENT	N 208	N NURP	PARAMETRIC STATISTICS[3] LEVEL OF SIGNIFICANCE: ONE-SIDED K-S-TEST 208	ONE-SIDED K-S-TEST NURP	T-STATISTIC ON MEANS	F-STATISTIC ON VARIANCES	NONPARAMETRIC STATISTICS LEVEL OF SIGNIFICANCE: TWO-SIDED K-S DISTRIBUTION TEST	WILCOXON RANK SUM MEDIAN TEST	HYPOTHESIS: SIGNIFICANTLY DIFFERENT DISTRIBUTION	SIGNIFICANTLY DIFFERENT MEAN OR MEDIAN	HIGHER MEAN/MEDIAN VALUE
RUNOFF (inches)	42	187	>0.20	0.10	0.09	0.38	0.07	0.07	NO	NO	---
TSS (lbs/ac)	42	181	>0.20	>0.20	*	0.15	*	*	NO	YES	208
COD (lbs/ac)	42	180	>0.20	>0.20	0.07	0.58	0.25	0.09	NO	NO	---
TOTAL-P (lbs/ac)	42	174	0.10	*	0.25	0.25	0.24	0.17	NO	NO	---
ORTHO-P (lbs/ac)	42	176	0.05	0.05	0.23	0.49	0.81	0.36	NO	NO	---
TOTAL-N (lbs/ac)	42	173	>0.20	>0.20	0.98	0.33	0.84	0.93	NO	NO	---
NITRATE-N (lbs/ac)	42	185	>0.20	0.10	*	0.61	0.06	*	NO	YES	NURP
AMMONIA-N	42	184	>0.20	*	*	0.32	*	*	YES	YES	NURP
TKN (lbs/ac)	42	175	0.10	>0.20	0.54	0.21	0.30	0.53	NO	NO	---
EPB (lbs/ac)	38	7	>0.20	0.15	0.28	*	*	*	NO	YES	208
PBF (lbs/ac)	--	--	--	--	--	--	--	--	--	--	---
EZN (lbs/ac)	41	151	>0.20	>0.20	*	0.06	*	*	NO	YES	208
ECU (lbs/ac)	32	36	>0.20	>0.20	*	0.21	*	*	NO	YES	208

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[1] LLSF and MDSF Pooled

[2] MDSF: Runoff Threshold < 0.8"

[3] Assumed Lognormal Distribution

*Level of Significance is less than 0.05

TABLE 18

COMPARISON OF NURP vs. 208 LAND USE RUNOFF STATISTICS
TOWNHOUSE/GARDEN APARTMENT
UNIT AREA LOADS

			PARAMETRIC STATISTICS[1]				NONPARAMETRIC STATISTICS				
			LEVEL OF SIGNIFICANCE				LEVEL OF SIGNIFICANCE		HYPOTHESIS		
			ONE-SIDED K-S-TEST								
CONSTITUENT	N 208	N NURP	208	NURP	T-STATISTIC ON MEANS	F-STATISTIC ON VARIANCES	TWO-SIDED K-S DISTRIBUTION TEST	WILCOXON RANK SUM MEDIAN TEST	SIGNIFICANTLY DIFFERENT DISTRIBUTION	SIGNIFICANTLY DIFFERENT MEAN OR MEDIAN	HIGHER MEAN/MEDIAN VALUE
RUNOFF (inches)	57	141	0.15	>0.20	0.14	0.60	0.22	0.13	NO	NO	---
TSS (lbs/ac)	57	139	>0.20	0.05	*	0.64	*	*	NO	YES	208
COD (lbs/ac)	57	136	>0.20	>0.20	*	0.67	0.34	0.05	NO	YES	208
TOTAL-P (lbs/ac)	57	137	0.05	>0.20	0.86	0.26	0.41	0.75	NO	NO	---
ORTHO-P (lbs/ac)	57	133	>0.20	0.15	*	0.67	*	*	NO	YES	NURP
TOTAL-N (lbs/ac)	57	137	>0.20	>0.20	0.49	0.19	0.50	0.34	NO	NO	---
NITRATE-N (lbs/ac)	57	141	0.20	>0.20	*	0.32	*	*	NO	YES	NURP
AMMONIA-N (lbs/ac)	57	141	>0.20	>0.20	*	0.86	*	*	NO	YES	NURP
TKN (lbs/ac)	57	137	0.05	>0.20	0.96	0.18	0.66	0.78	NO	NO	---
EPB (lbs/ac)	57	28	>0.20	>0.20	*	0.16	*	*	NO	YES	208
PBF (lbs/ac)	--	--	--	--	--	--	--	--	--	--	---
EZN (lbs/ac)	57	130	>0.20	>0.20	*	0.33	*	*	NO	YES	208
ECU (lbs/ac)	52	34	>0.20	0.20	0.79	*	*	*	NO	NO	---

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[1] Assumed Lognormal Distribution
*Level of Significance is less than 0.05

TABLE 19

COMPARISON OF NURP vs. 208 LAND USE RUNOFF STATISTICS
SHOPPING CENTER
UNIT AREA LOADS

			PARAMETRIC STATISTICS[1] LEVEL OF SIGNIFICANCE				NONPARAMETRIC STATISTICS LEVEL OF SIGNIFICANCE		HYPOTHESIS		
			ONE-SIDED K-S-TEST		T-STATISTIC ON MEANS	F-STATISTIC ON VARIANCES	TWO-SIDED K-S DISTRIBUTION TEST	WILCOXON RANK SUM MEDIAN TEST	SIGNIFICANTLY DIFFERENT DISTRIBUTION	SIGNIFICANTLY DIFFERENT MEAN OR MEDIAN	HIGHER MEAN/MEDIAN VALUE
CONSTITUENT	N 208	N NURP	208	NURP							
RUNOFF (inches)	40	85	>0.20	>0.20	0.09	0.85	0.37	0.09	NO	NO	---
TSS	40	84	>0.20	>0.20	*	*	*	*	NO	YES	208
COD	40	83	>0.20	>0.20	*	0.20	*	*	NO	YES	208
TOTAL-P	40	84	>0.20	>0.20	*	0.09	*	*	NO	YES	208
ORTHO-P	36	76	0.10	>0.20	*	0.87	*	*	NO	YES	NURP
TOTAL-N	40	78	>0.20	>0.20	0.76	0.62	0.88	0.71	NO	NO	---
NITRATE-N	40	80	>0.20	>0.20	*	0.88	*	*	NO	YES	NURP
AMMONIA-N	40	83	>0.20	>0.20	0.20	0.35	0.44	0.19	NO	NO	---
TKN	40	83	>0.20	>0.20	*	0.21	*	*	NO	YES	208
EPB	38	5	0.15	>0.20	0.28	0.32	*	*	NO	YES	208
PBF	--	--	--	--	--	--	--	--	--	--	---
EZN	38	56	>0.20	0.10	*	0.22	*	*	NO	YES	208
ECU	37	21	0.15	>0.20	0.21	0.83	*	*	NO	YES	208

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[1] Assumed Lognormal Distribution

*Level of Significance is less than 0.05

- Medium Density Single Family: Table 16 shows that for total-P and total-N, the NURP and the 208 medium density single family datasets are not significantly different. TSS loadings are significantly higher at the 208 sites, where median loading rates for the NURP medium density single family land use category are approximately 25% of the 208 values. The higher nitrate-N and ammonia-N loadings are expected, given the higher soluble nitrogen fractions characterizing the NURP dataset. Median extractable zinc loadings are significantly higher at the 208 sites. A comparison of median loading rates shows that the NURP medians are approximately 33% of the 208 values.

- Townhouse/Garden Apartment: Although the NURP total-P and total-N loads are not significantly different from the 208 datasets, the results in Table 18 show that the NURP sites have significantly higher inorganic fractions for both phosphorus (ortho-P) and nitrogen (ammonia-N and nitrate-N). TSS loadings are also significantly lower at the NURP townhouse sites. Although this may be due in part to the infiltration BMP serving the Dandridge NURP site, inspection of the box and whisker plots shows that the Stedwick NURP site (which is an uncontrolled, curb and gutter site at the inflow station) also exhibits TSS loadings which are significantly lower. A ratio of the median loading rate shows that the NURP dataset are approximately 42% of the 208 values. As a result of the higher inorganic fractions of the NURP dataset, COD loadings are significantly lower in the NURP datasets. Comparison of the NURP and 208 medians shows the NURP loading rate to be approximately 60% of 208 loading rate. Extractable lead and zinc loading rates are also significantly lower at the NURP townhouse site with the NURP median values 33% and 66% lower, respectively, than the 208 median values.

- Shopping Center: Comparison of the shopping center datasets, as shown in Table 19, would appear to show drastic changes in the land use/nonpoint loading relationship developed from the 208 study monitoring data. Only total-N and ammonia-N loadings are not significantly lower at the NURP monitoring sites. However, since there were infiltration type BMP's serving both NURP sites, these results would suggest possible benefits of controls such as these rather than marked changes in the land use/runoff quality relationships. Given the reductions in TSS loadings which were noted at all NURP residential categories, and the increased inorganic fractions which appear to be significant at the more impervious NURP land use datasets, it is felt that while some of the differences noted in Table 19 may be significant with regard to uncontrolled loading comparisons, the data does not lend itself to quantifying these changes. This conclusion applies also to the heavy metals loadings which were also found to be significantly lower for the NURP shopping center datasets.

- Pollutant Fractions: The NURP and 208 pollutant fraction datasets were also compared using the combination of parametric and non-parametric techniques described above. These statistics are summarized by land use in Tables 20 through 23. The pollutant fraction dataset was assumed to be normally distributed for the purposes of the parametric tests. The results of these tests are remarkably consistent; the NURP land use datasets exhibit significantly higher fractions, both soluble and inorganic, for nitrogen and phosphorus. The only exception to this is that the soluble P fractions for the large lot single family datasets do not appear to be significantly different. Soluble zinc fractions are also significantly higher for all NURP land use datasets.

Summary and Recommendations

Nonpoint pollution monitoring data collected during the 1976-1977 NVPDC-VPI&SU 208 field study was compared to the substantially larger NURP nonpoint database. The purpose of this analysis is to verify and/or refine land use/nonpoint loading relationships which were developed from the more limited 208 database. For nonpoint source pollutants for which it has been shown that there are no significant differences either in frequency distribution or in central value between the NURP land use datasets and the 208 land use datasets, no changes in the land use/nonpoint source relationships are warranted. In other words, where the NURP database, with reasonable confidence, has been shown to be statistically similar to the 208 database; land use/nonpoint pollution relationships drawn from the 208 dataset can be considered verified. Where significant differences between the NURP and the 208 datasets have been identified and sufficient consistent data is available within the NURP database, refinement of the land use/nonpoint source relationships is warranted provided that the monitoring sites within a given land use category are representative of that land use.

The recommendations presented below are intended to update the nonpoint source desktop model which was developed from the 208 database. There were extensive gaps in the NURP onsite precipitation records which made similar NURP modeling efforts unfeasible. Less than 30% of the station-storms monitored had corresponding onsite, continuous precipitation records. Of the storms which were not monitored, no onsite records were available. NVPDC's preliminary assessments of the precipitation records determined that many of the onsite, storm event, precipitation totals were not in agreement with surrounding gages and often could not be reasonably related to runoff (e.g., runoff-rainfall ratios which were greater than one).

The 208 land use/nonpoint pollution relationships were developed from annual EPA nonpoint source (NPS) model loading projections. The NPS model was calibrated to develop a single set of land use/nonpoint pollution relationships for each land use category (1,2). The calibrated models were subsequently executed with an hourly rainfall record for a one-year period of average wetness. Percent impervious cover factors and soils parameters were than adjusted to derive projections for varying land use densities

TABLE 20

COMPARISON OF NURP vs. 208 POLLUTANT FRACTIONS; LARGE LOT SINGLE FAMILY

			PARAMETRIC STATISTICS				NONPARAMETRIC STATISTICS		HYPOTHESIS		
			ONE-SIDED K-S-TEST		T-STATISTIC ON	F-STATISTIC ON	TWO-SIDED K-S DISTRIBUTION	WILCOXON RANK SUM	SIGNIFICANTLY DIFFERENT	SIGNIFICANTLY DIFFERENT	HIGHER MEAN/MEDIAN
FRACTION	N 208	N NURP	208	NURP	MEANS	VARIANCES	TEST	MEDIAN TEST	DISTRIBUTION	MEAN OR MEDIAN	VALUE
TOTAL SOLUBLE-P	18	71	>0.20	>0.20	0.05	0.25	0.19	0.07	NO	NO	---
ORTHO-P	18	69	0.20	>0.20	*	*	*	*	NO	YES	NURP
TOTAL SOLUBLE-N	18	72	>0.20	0.10	*	0.11	0.17	0.07	NO	YES	NURP
INORGANIC-N	18	73	>0.20	0.05	*	0.22	*	*	NO	YES	NURP
SOLUBLE-ZINC	17	48	>0.20	0.15	*	1.00	*	*	NO	YES	NURP

*Level of significance is less than 0.05

TABLE 21

COMPARISON OF NURP vs. 208 POLLUTANT FRACTIONS; MEDIUM DENSITY SINGLE FAMILY

			PARAMETRIC STATISTICS				NONPARAMETRIC STATISTICS		HYPOTHESIS		
			ONE-SIDED K-S-TEST		T-STATISTIC ON MEANS	F-STATISTIC ON VARIANCES	TWO-SIDED K-S DISTRIBUTION TEST	WILCOXON RANK SUM MEDIAN TEST	SIGNIFICANTLY DIFFERENT DISTRIBUTION	SIGNIFICANTLY DIFFERENT MEAN OR MEDIAN	HIGHER MEAN/MEDIAN VALUE
FRACTION	N 208	N NURP	208	NURP							
TOTAL SOLUBLE-P	24	102	>0.20	*	*	0.06	*	*	YES	YES	NURP
ORTHO-P	24	98	>0.20	0.10	*	*	*	*	NO	YES	NURP
TOTAL SOLUBLE-N	24	102	>0.20	*	*	*	*	*	YES	YES	NURP
INORGANIC-N	24	102	>0.20	>0.20	*	0.58	*	*	NO	YES	NURP
SOLUBLE-ZINC	24	60	*	*	0.43	*	*	*	YES	YES	NURP

*Level of significance is less than 0.05

TABLE 22

COMPARISON OF NURP vs. 208 POLLUTANT FRACTIONS: TOWNHOUSE/GARDEN APARTMENT

			PARAMETRIC STATISTICS				NONPARAMETRIC STATISTICS		HYPOTHESIS		
			ONE-SIDED K-S-TEST								
FRACTION	N 208	N NURP	208	NURP	T-STATISTIC ON MEANS	F-STATISTIC ON VARIANCES	TWO-SIDED K-S DISTRIBUTION TEST	WILCOXON RANK SUM MEDIAN TEST	SIGNIFICANTLY DIFFERENT DISTRIBUTION	SIGNIFICANTLY DIFFERENT MEAN OR MEDIAN	HIGHER MEAN/MEDIAN VALUE
TOTAL SOLUBLE-P	57	132	*	*	*	*	*	*	YES	YES	NURP
ORTHO-P	56	127	0.05	0.20	*	0.08	*	*	NO	YES	NURP
TOTAL SOLUBLE-N	57	136	>0.20	*	*	0.67	*	*	YES	YES	NURP
INORGANIC-N	57	137	>0.20	>0.20	*	*	*	*	NO	YES	NURP
SOLUBLE-ZINC	57	103	0.05	*	*	0.16	*	*	YES	YES	NURP

*Level of significance is less than 0.05

TABLE 23

COMPARISON OF NURP vs. 208 POLLUTANT FRACTIONS: SHOPPING CENTER

			PARAMETRIC STATISTICS				NONPARAMETRIC STATISTICS		HYPOTHESIS		
			ONE-SIDED K-S-TEST		T-STATISTIC ON MEANS	F-STATISTIC ON VARIANCES	TWO-SIDED K-S DISTRIBUTION TEST	WILCOXON RANK SUM MEDIAN TEST	SIGNIFICANTLY DIFFERENT DISTRIBUTION	SIGNIFICANTLY DIFFERENT MEAN OR MEDIAN	HIGHER MEAN/MEDIAN VALUE
FRACTION	N 208	N NURP	208	NURP							
TOTAL SOLUBLE-P	40	82	>0.20	*	*	0.61	*	*	YES	YES	NURP
ORTHO-P	37	69	*	0.20	*	*	*	*	YES	YES	NURP
TOTAL SOLUBLE-N	40	75	>0.20	*	*	*	*	*	YES	YES	NURP
INORGANIC-N	40	78	>0.20	*	*	0.64	*	*	YES	YES	NURP
SOLUBLE-ZINC	38	44	0.10	*	*	0.59	*	*	YES	YES	NURP

*Level of significance is less than 0.05

within each land use classification and for different soil textures. For urban land use categories, these NPS calibrations involved iterative adjustment of dry weather accumulation rates to achieve acceptable agreement between simulated and observed storm event total loads (lbs) (1,2,9). A single set of dry weather accumulation rates was developed for each urban land use category. Previous NPS model calibration studies (2,9,10) have concluded that it is reasonable to assume that the pollutant accumulation rate parameters used in the model are directly proportional to long term loading rates associated with urban land uses. This assumption is used to adjust initial estimates of model parameters in order to achieve better agreement between observed and simulated loads. Although insufficient meteorologic data is available to conduct a model calibration study of the NURP watersheds, the ratio of the median loading rates at the NURP and the 208 studies can be used to adjust annual loading projections which were previously based on long term loading rates derived from the 208 database. The 208 land use/nonpoint pollution loading relationships included average annual loading rates (lbs/ac/yr) for BOD, total phosphorus, total nitrogen, extractable lead, extractable zinc, and sediment. The plant nutrient fractions and dissolved fractions developed during the 208 study were determined by using the mean values observed within each land use category. A summary of findings and recommendations is presented below:

- Biochemical Oxygen Demand (BOD): The NURP monitoring effort emphasized COD rather than BOD. Only 31 of the 583 station-storms monitored include BOD_5 measurements. A check of the COD/BOD ratios showed high variability across the NURP and 208 land use categories. In both studies, COD/BOD ratios ranged from approximately 6-20. In terms of COD loadings, no significant differences were found between the NURP and 208 large lot single family and medium density single family land use categories. At the townhouse and shopping center land use categories, NURP loadings were significantly lower. This is probably due to the lower suspended loadings of organic P and N which are discussed below. Given the limited amount of BOD data available, no changes are recommended.

- Total Phosphorus: For all land use categories except shopping center, no significant differences between the NURP and 208 unit area loading datasets were found. Since both NURP shopping center sites were served by infiltration type BMP's, it is felt that these sites cannot be considered representative of uncontrolled runoff conditions. Therefore, although significantly lower loading rates were found at the NURP shopping center sites, no change is recommended. For the residential land uses, this analysis provides a good indication that the 208 land use/runoff relationships are (1) transferable to different locations, and (2) are applicable under a variety of hydrometeorologic conditions.

- Total Nitrogen: No significant differences were found between the NURP and 208 datasets for any of the four categories considered.

In terms of median unit area loading rates, the results are remarkably similar. Within three of the four land use categories, the NURP and the 208 medians are within 10% of each other. Within all categories, the median loading rates are within 15% of each other. These results would also tend to verify the 208 land use/total-N relationships under a variety of locational and hydrometeorologic changes.

- Extractable Zinc: Significantly lower extractable zinc loadings were found for all NURP land use categories except large lot single family. The NURP datasets exhibit lower median extractable zinc loadings but higher soluble zinc fractions. This change can be attributed to much lower suspended zinc loadings. These results are consistent with the COD and TSS results presented below. Since the medians and distributions for extractable zinc loadings are very similar for both large lot and medium density single family (as noted in Table 13 and Figure D-23), it is recommended that these land uses be pooled in terms of extractable zinc loading projections. It is further recommended that the annual loading rates developed from the 208 datasets be adjusted by the ratio of the median values of the NURP large lot and 208 large lot datasets (0.001:0.002). Since these differences are thought to be due to different land use/loading relationships, these changes are recommended for all soil textures given in the 208 land use projections. In recent studies (11,12,13), the NPS model, which was used to differentiate between soils textures for the 208 annual loading projections, has been demonstrated to be very effective in simulating runoff from varying soils textures. Similar changes are recommended for the townhouse/garden apartment land use category. The ratio of the NURP and 208 median loading rates is 0.002:0.003; therefore, a 33% reduction in annual loading rates is recommended. The refinements to the annual loading rates are summarized below:

		UNCONTROLLED LOADING RATE (lbs/ac/yr)			
LAND USE	% IMPERVIOUSNESS	CLAY LOAM SOILS	SILT LOAM SOILS	LOAM SOILS	SANDY LOAM SOILS
Single Family Residential (0.5-6.0 DU/ac)	9%-35%	0.10-0.14	0.09-0.14	0.09-0.13	0.06-0.11
Townhouse/ Garden Apt. (6.0-20 DU/ac)	35%-50%	0.33-0.42	0.32-0.41	0.30-0.39	0.26-0.36

- Extractable Lead: Significant differences in extractable lead loadings were noted at all but the medium density single family land use categories. The NURP land use datasets were lower in all cases. Given the limited number of datapoints available (e.g., there were five or less at 3 of 4 land use categories) and the change in analytical techniques from flame AA (e.g., detection limit 100 ug/L) to furnace AA (e.g., detection limit 1/ug/L), very little confidence can be ascribed to using this data to determine long-term land use/runoff quality relationships. There is considerably more data available for extractable zinc loading rates. Inspection of median (and mean) loading rates for lead and zinc suggests that these pollutants exhibit similar land use/runoff relationships. The NURP large lot single family and townhouse land use categories have identical loading rates for both lead and zinc. Medium density single family exhibits higher loading rates, however this is based on only two datapoints. Therefore, reductions in projected annual lead loadings are recommended to be the same as the zinc loading reduction recommended above. These are: (a) a 50% reduction for the single family land use category, and (b) a 33% reduction for townhouse garden apartment. These recommendations are summarized below:

LAND USE	% IMPERVIOUSNESS	UNCONTROLLED LOADING RATE (lbs/ac/yr) CLAY LOAM SOILS	SILT LOAM SOILS	LOAM SOILS	SANDY LOAM SOILS
Single Family Residential (0.5-6.0 DU/ac)	9%-35%	0.07-0.13	0.07-0.13	0.07-0.13	0.06-0.12
Townhouse/ Garden Apt. (6.0-20 DU/ac)	35%-50%	0.44-0.55	0.44-0.54	0.40-0.52	0.35-0.49

- Total Suspended Sediment: All NURP land use categories exhibited significantly lower sediment loading rates. As previously discussed, this is thought to be in large part attributable to the two different sampling techniques used in the two studies. The flow composite sampling technique used during the NURP monitoring study should provide a more accurate representation of sediment loadings. The repercussions of overestimating TSS loadings include overestimation of suspended loadings and under-estimation of dissolved loadings. These subjects are addressed below. Since the differences in TSS loadings between the NURP and 208 datasets is thought to be a function of sampling technique rather than a change in land use/runoff relationships, a constant adjustment factor is recommended for all residential land use categories. The recommended adjustment is the average ratio of median loading rates for large lot single family (e.g., 0.32), medium density single family (e.g., 0.25), and townhouse/garden apartment residential (e.g., 0.42). Therefore, annual sediment loading rates should be adjusted downward by a factor of 0.33. The refinements to the annual loading rates are summarized below:

LAND USE	% IMPERVIOUSNESS	UNCONTROLLED LOADING RATE (tons/ac/yr) CLAY LOAM SOILS	SILT LOAM SOILS	LOAM SOILS	SANDY LOAM SOILS
Large Lot Single Family (0.5-2.0 DU/ac)	9%-18%	0.04-0.05	0.04-0.05	0.03-0.05	0.02-0.04
Medium Density Single Family (3.0-6.0 DU/ac)	20%-35%	0.05-0.08	0.05-0.08	0.05-0.07	0.04-0.07
Townhouse/ Garden Apt. (6.0-20 DU/ac)	35%-50%	0.09-0.11	0.09-0.11	0.08-0.10	0.07-0.09

- Pollutant Fractions: The 208 land use/runoff quality relationships relied on the means of the observed ratios of plant nutrient fractions to total-P and total-N. These mean ratios were used to distribute annual total-P and total-N loading projections among organic and inorganic forms. Similarly, dissolved and suspended fractions of total-P and total-N, and heavy metals were distributed according to the means of the observed storm event values. Since the NURP nonpoint database is approximately two to four times larger than the 208 database and the NURP datasets have been shown to exhibit significantly lower TSS loadings, it is recommended that the mean pollutant fractions characterizing the NURP land use datasets be used to refine the 208 residential land pollutant fraction allocations. The recommended fractions are summarized below:

LAND USE	FRACTION SOLUBLE-P	FRACTION ORTHO-P	FRACTION SOLUBLE-N	FRACTION INORGANIC-N	FRACTION SOLUBLE ZINC
Large Lot Single Family (0.5-2.0 DU/ac)	0.68	0.52	0.82	0.36	0.72
Medium Density Single Family (2.0-6.0 DU/ac)	0.77	0.57	0.88	0.45	0.78
Townhouse/ Garden Apt. (6.0-20 DU/ac)	0.63	0.54	0.79	0.49	0.69

The higher dissolved and inorganic fractions of phosphorus and nitrogen which the NURP results have shown with remarkable consistency suggest two probable consequences. First, the NURP findings indicate that the percentage of total phosphorus and total nitrogen which is most readily available (e.g., that fraction which is most readily available for algal uptake) is probably higher than was estimated based upon the 208 dataset. Previous studies (1) suggested that a relationship by Cowen and Lee (5) be used to define an upper limit of biologically available phosphorus. This relationship is:

Available P = 100% (Dissolved P) + 30% (Suspended P)

Applying this relationship to the fraction of dissolved and suspended P observed at the NURP land use categories yields a biologically available fraction ranging from 74% -84% as opposed to the 59%-69% fractions determined from the 208 datasets. For available-N, the recommended guideline was 70% of total-N. Since NURP total-N loadings are not significantly different, available-N should be reasonably similar. The significantly lower suspended fractions of total-P, total-N and extractable zinc would suggest lower removal rates for BMP's which rely on sedimentation as the primary removal mechanism.

IV. ATMOSPHERIC LOADINGS

Introduction

Wetfall/dryfall data was collected at four sites, three of which were in close proximity to NURP runoff monitoring stations. The wetfall/dryfall stations were located at Haines Point, D.C., Burke Village Centre, Va. (two stations: one roof-mounted and one ground level installation) and Stedwick, Md. The wetfall and dryfall data are summarized in Appendices F and G, respectively. The number of wetfall and dryfall observations and the dates of the first and last samples are as follows:

	Monitoring Period	Number of Wetfall Samples	Number of Dryfall Samples
Haines Point (D.C.)	12/20/80-1/2/82	39	52
Burke Village Centre Roof (VA)	2/10/81-12/30/81	39	49
Burke Village Centre Ground (VA)	3/22/81-12/23/81	30	38
Stedwick (Md.)	6/11/81-12/16/81	17	29

Wetfall Analysis

Table 24 summarizes mean wetfall concentrations at the individual stations and for all stations pooled. Both volume weighted means (using inches of precipitation as the weighting factor) and log means are presented. The pH data, which is based on laboratory measurements (e.g., not in situ data), indicates that, rainfall at all stations is quite

TABLE 24

MEAN CONCENTRATIONS AT NURP WETFALL STATIONS

	BURKE VILLAGE CENTRE (ROOF)			BURKE VILLAGE CENTRE (GROUND)			STEDWICK			HAINES PT.			ALL STATIONS POOLED		
CONSTITUENT	N	VOLUME WEIGHTED MEAN	MEAN*	N	VOLUME WEIGHTED MEAN	MEAN*	N	VOLUME WEIGHTED MEAN	MEAN*	N	VOLUME WEIGHTED MEAN	MEAN*	N	VOLUME WEIGHTED MEAN	MEAN*
pH	37	4.1	4.1	29	4.0	4.0	16	4.1	4.1	39	4.1	4.0	121	4.1	4.0
COD (mg/L)	36	7.0	10.8	30	10.8	13.3	16	8.2	10.5	33	10.7	15.5	115	9.1	11.7
TOTAL-P (mg/L)	36	0.02	0.03	27	0.02	0.03	14	0.02	0.02	30	0.03	0.04	118	0.02	0.03
ORTHO-P (mg/L)	17	0.01	0.01	10	0.01	0.01	8	0.01	0.02	17	0.01	0.02	119	0.01	0.01
TOTAL-N (mg/L)	36	1.0	1.2	30	1.0	1.2	16	0.9	1.2	34	1.1	1.3	116	1.0	1.2
NITRATE (mg/L)	39	0.5	0.6	30	0.6	0.6	17	0.4	0.6	35	0.5	0.6	121	0.5	0.6
AMMONIA (mg/L)	39	0.3	0.3	30	0.2	0.3	17	0.03	0.4	35	0.2	0.3	121	0.2	0.3
TKN (mg/L)	36	0.5	0.6	30	0.5	0.6	16	0.05	0.6	34	0.6	0.7	116	0.5	0.6
EPB (ug/L)	1	--	--	1	--	--	1	--	--	1	--	--	4	116	113
EZN (ug/L)	13	91	81	21	134	162	7	101	282	19	37	44	60	95	111
ECU (ug/L)	0	--	--	2	24	26	5	21	23	4	54	54	11	27	33

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*Assumed Lognormal Distribution

acidic. Mean pH values* of wetfall samples are consistently between 4.0-4.1. Laboratory measurement of pH would tend to yield overestimates compared to in situ pH because, while there are no known processes which would decrease the pH of a given sample, natural buffering would tend to elevate pH, especially when the relatively long sampling durations are taken into consideration. The pH of rainwater can be as low as 5.6 due to absorption of carbon dioxide from the air (14). Below this value so-called mineral acidity is present. This mineral acidity is generally considered to be caused by sulfate or nitrogen oxides in the atmosphere. Although the laboratory measurements of the pH of wetfall were quite acidic, Figure 3 shows box and whisker plots for pH measurements in both wetfall and runoff from nearby or onsite NURP monitoring stations. Laboratory pH in runoff tends to be in the 6.8-7.0 range (e.g., well buffered). Although the wetfall data suggest considerable evidence of acid rain conditions in the Metropolitan area, the relatively normal pH measurement in runoff indicates that, at present, there does not appear to be an adverse impact on surface waters. This implies that the buffering capacity (i.e., the capacity to neutralize acidity) of area soils is sufficient to offset the impact of acid deposition. Total phosphorus and ortho-phosphorus concentrations are typically 5%-10% of the event mean concentrations measured in runoff. Total nitrogen concentrations are typically 40%-50% of the runoff concentrations. The nitrogen fraction concentrations, as a percent of comparable runoff concentrations, are highly variable, ranging from about 40% to well over 100%. A more in-depth analysis of wetfall/runoff comparisons is presented below.

The Duncan multiple range test (6) was used to check for subpopulations within the wetfall datasets. The Duncan test detects significant differences in the means of specified subpopulations. Subpopulations are assigned a letter; groups of subpopulations with the same letter or Duncan Grouping are not significantly different at a specified confidence interval. Note that it is possible for a subpopulation to belong to more than one Duncan Grouping. The datasets were screened for differences between stations (e.g., locational differences) and also for seasonal differences using the pooled wetfall dataset. The results are summarized in Table 25 and 26. Based on the results of one-sided K-S tests, lognormal distributions were assumed for these tests. On the first line of each cell, the mean and the median values are shown. The sample sizes are given on the bottom line. The Duncan Grouping is shown on the middle line of each cell. Subpopulations with the same letter have means which are not significantly different at the 95% confidence interval. With the exception of total-P, the results in Tables 25 and 26 indicate that there are no significant differences between stations for pH, COD, ortho-P, and the nitrogen forms. The results also indicate that atmospheric loadings in suburban Maryland and in the District of Columbia are quite similar to loadings in suburban Virginia. Extractable zinc was the only heavy metal included in this analysis with sufficient data to be conclusive. The Burke Centre Roof and Haines Point stations exhibit significantly lower means. While no ready

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*Means were computed from the [H^+] and converted to pH.

FIGURE 3

Comparison of Laboratory pH Measurements at NURP Wetfall Stations and Corresponding Runoff Stations

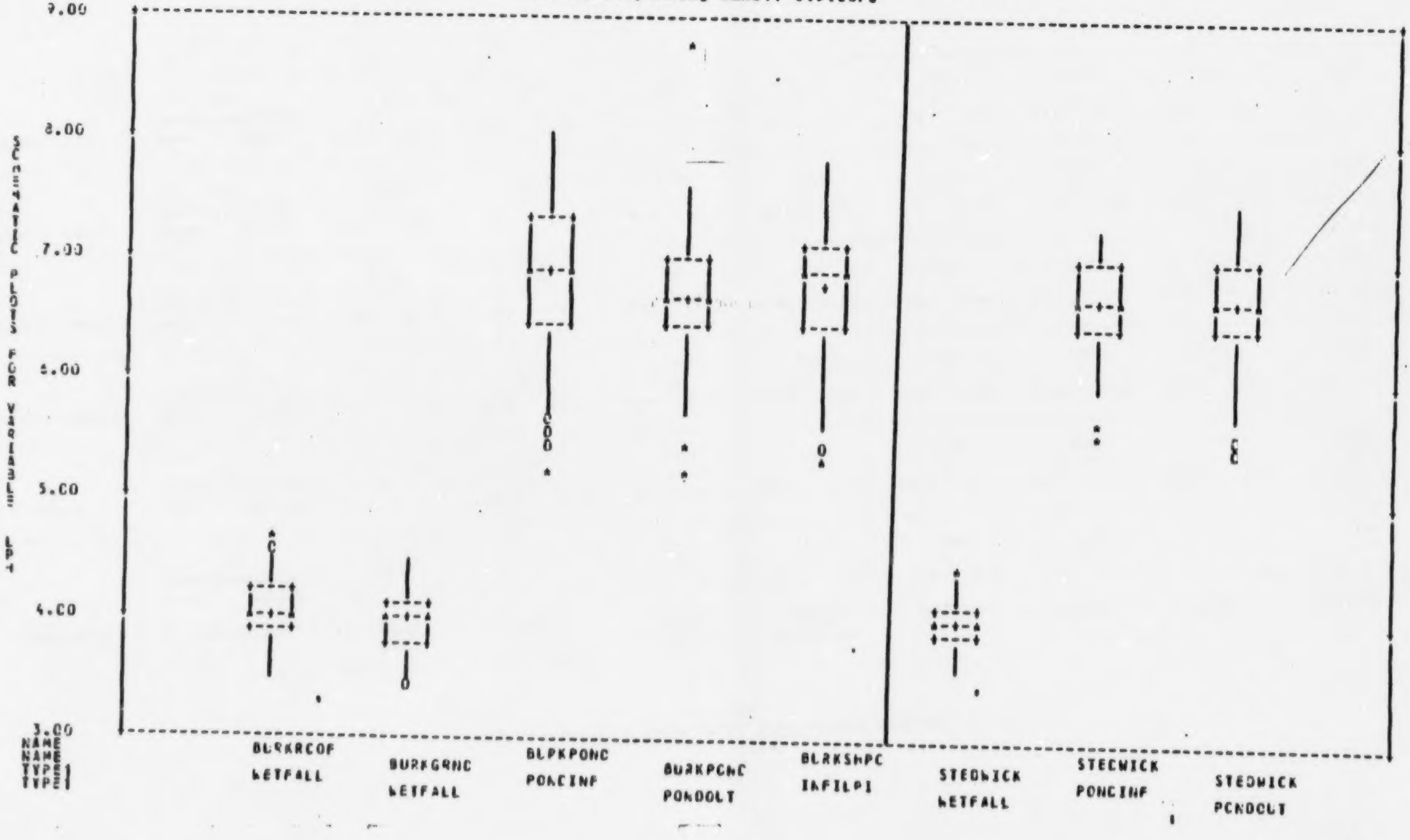

TABLE 25

DUNCAN'S MULTIPLE RANGE TEST: NURP WETFALL STATIONS
$\alpha = 0.05$

CONSTITUENT	STATISTIC	BURKE CENTRE -ROOF- (SHPC)	BURKE CENTRE -GROUND- (SHPC)	STEDWICK (TIGA)	HAINES PT. (DWTN)	SPRING	SUMMER	FALL	WINTER
pH	MEAN MEDIAN DUNCAN GROUPING (N)	4.1 4.0 A (37)	4.0 4.0 A (29)	4.1 4.1 A (16)	4.0 4.0 A (39)	4.0 4.0 B (28)	4.0 4.0 B (41)	4.0 4.0 B (38)	4.3 4.2 A (14)
COD (mg/L)	MEAN MEDIAN DUNCAN GROUPING (N)	13.3 9.2 A (31)	10.8 8.7 A (29)	10.5 8.4 A (16)	15.5 10.6 A (33)	16.7 11.5 A (20)	12.1 9.2 A (38)	12.4 9.0 A (37)	10.4 7.9 A (14)
TOTAL-P (mg/L)	MEAN MEDIAN DUNCAN GROUPING (N)	0.03 0.02 A/B (36)	0.03 0.02 A/B (27)	0.02 0.02 B (14)	0.04 0.03 A (30)	0.04 0.04 A (22)	0.02 0.02 B (36)	0.03 0.03 A (37)	0.02 0.02 B (12)
ORTHO-P (mg/L)	MEAN MEDIAN DUNCAN GROUPING (N)	0.01 0.01 A (17)	0.01 0.01 A (10)	0.02 0.01 A (8)	0.02 0.01 A (17)	0.01 0.01 A (10)	0.01 0.01 A (15)	0.02 0.02 A (20)	0.01 0.01 A (7)
TOTAL-N (mg/L)	MEAN MEDIAN DUNCAN GROUPING (N)	1.2 1.1 A (36)	1.2 1.1 A (30)	1.2 1.1 A (16)	1.3 1.2 A (34)	1.6 1.4 A (24)	1.1 1.0 B (41)	1.2 1.1 A/B (35)	1.0 0.9 B (16)
NITRATE (mg/L)	MEAN MEDIAN DUNCAN GROUPING (N)	0.6 0.5 A (39)	0.6 0.5 A (30)	0.6 0.5 A (17)	0.6 0.5 A (35)	0.9 0.7 A (26)	0.6 0.5 B (41)	0.6 0.5 B (38)	0.4 0.3 C (16)

TABLE 26

DUNCAN'S MULTIPLE RANGE TEST: NURP WETFALL STATIONS

$\alpha = 0.05$

CONSTITUENT	STATISTIC	BURKE CENTRE -ROOF- (SHPC)	BURKE CENTRE -GROUND- (SHPC)	STEDWICK (THGA)	HAINES PT. (DWTN)	SPRING	SUMMER	FALL	WINTER
AMMONIA (mg/L)	MEAN MEDIAN DUNCAN GROUPING (N)	0.3 0.2 A (39)	0.3 0.2 A (30)	0.4 0.3 A (17)	0.3 0.3 A (35)	0.4 0.3 A (26)	0.2 0.2 B (41)	0.5 0.4 A (38)	0.2 0.2 B (16)
TKN (mg/L)	MEAN MEDIAN DUNCAN GROUPING (N)	0.6 0.5 A (36)	0.6 0.5 A (30)	0.6 0.5 A (16)	0.7 0.6 A (34)	0.7 0.6 A (24)	0.5 0.4 B (41)	0.7 0.6 A (35)	0.6 0.5 A/B (16)
EPB (ug/L)	MEAN MEDIAN DUNCAN GROUPING (N)	-- -- C (1)	-- -- B (1)	-- -- A (1)	-- -- D (1)	-- -- -- (0)	-- -- A (1)	110 110 B (3)	- -- -- (0)
EZN (ug/L)	MEAN MEDIAN DUNCAN GROUPING (N)	81 53 B/C (13)	162 123 A (21)	202 91 A/B (7)	44 36 C (19)	79 51 A (12)	134 81 A (19)	126 73 A (23)	77 49 A (6)
ECU (ug/L)	MEAN MEDIAN DUNCAN GROUPING (N)	-- -- -- (0)	26 24 A (2)	23 23 A (5)	54 45 A (4)	51 38 A (3)	23 23 A (5)	-- -- -- (0)	40 36 A (3)

explanation regarding the Haines Point station is known, the higher zinc concentrations at the Stedwick and Burke Village Center (ground level) stations are probably due in part to the galvanized steel fences which enclosed both these sites.

There do appear to be subtle seasonable differences for a number of constituents. It was not determined whether these were due to anomalies characterizing the monitoring period (e.g., a large number of thunderstorms may influence the amount of nitrogen measured during a given season) or if they are due to normal seasonal variations of temperature and precipitation.

In terms of pH and nutrients concentrations, the results in Table 25 and Table 26 show that there do not appear to be major locational differences in precipitation volumes. Measurements of pH tend to be slightly, albeit significantly higher in winter (i.e., December-February). Total-P and total-N concentrations are slightly lower in the summer (e.g., June-August) and winter periods. Ammonia-N and TKN concentrations follow similar patterns. Nitrate-N concentrations are higher in the spring (e.g., March-May) and lower in the winter with the summer and fall (e.g., September-November) at intermediate levels. Extractable zinc shows no seasonality, possibly because the sources of zinc are primarily anthropogenic.

Loading comparisons were made to assess the impact of atmospheric loadings on runoff quality. VPI&SU provided NVPDC with measured total rainfall data which was added to the wetfall dataset so that wetfall loadings could be related to runoff loadings. Only synoptic events (e.g., those events which were synchronously monitored at both the wetfall station and the runoff station) were used in this analysis. When the wetfall sample represented more than one event, corresponding runoff loads were combined. Table 27 summarizes the synoptic wetfall loading/runoff loading comparisons. The wetfall stations located at Burke Village Centre (both roof and ground) were compared to both the Burke Pond Inflow station (e.g., a medium density single family site) and the Burke Village Center runoff site (e.g., a shopping center site served by an infiltration type BMP). These comparisons are warranted given the absence of locational differences described above. Loading data from the wetfall station at Stedwick is compared to the runoff loadings monitored at this site. Table 27 shows that the total precipitation recorded at the wetfall sampler is generally within 20% of the total precipitation monitored at the runoff monitoring station which is a good indication that the events being compared are synoptic.

Comparisons between wetfall loadings and pollutant loadings in runoff are presented below:

- o Phosphorus forms: Table 27 shows that wetfall can contribute a significant amount of total-P found in runoff. The highly impervious Burke Centre Shopping Center site exhibits total wetfall loads which are 10%-15% of the total runoff loads. Since most of the rainfall would be converted to runoff at a highly impervious

TABLE 27

COMPARISON OF SYNOPTIC EVENTS AT RUNOFF vs. WETFALL STATIONS CUMULATIVE LOADS (lbs/ac) AND RATIO OF WETFALL LOADING/RUNOFF LOADING (%)

CONSTITUENT	BURKE POND (INFLOW) LAND USE: HDSF						BURKE VILLAGE CENTRE LAND USE: SHPC						STEDWICK (DRY POND INFLOW) LAND USE: THGA		
	RUNOFF	WETFALL^A	RATIO	RUNOFF	WETFALL^B	RATIO	RUNOFF	WETFALL^A	RATIO	RUNOFF	WETFALL^B	RATIO	RUNOFF	WETFALL^C	RATIO
N		26			20			25			18			6	
TOTAL-PRECIPITATION (inches)	22.8	25.1	110%	18.7	18.0	96%	24.5	26.8	110%	18.9	17.9	95%	8.3	10.2	12.3%
TOTAL-P (lbs/ac)	0.33	0.12	36%	0.11	0.07	64%	0.88	0.13	15%	0.69	0.07	10%	0.10	0.02	20%
ORTHO-P (lbs/ac)	0.16	0.03	19%	0.06	0.01	17%	0.42	0.03	7%	0.35	0.01	3%	0.02	0.005	25%
ORGANIC-P (lbs/ac)	0.17	0.09	53%	0.05	0.06	120%	0.46	0.10	22%	0.34	0.06	18%	0.08	0.015	19%
TOTAL-N (lbs/ac)	3.20	5.54	173%	1.01	4.12	408%	9.50	6.21	65%	7.99	4.01	50%	0.78	1.90	244%
TKN (lbs/ac)	2.17	2.54	117%	0.69	1.73	251%	4.26	3.04	71%	3.47	1.66	48%	0.61	0.85	139%
NITRATE (lbs/ac)	1.03	3.00	291%	0.32	2.39	747%	5.24	3.17	60%	4.52	2.35	52%	0.17	1.05	618%
EZN (lbs/ac)	0.039	0.043	110%	0.017	0.434	2553%	0.202	0.048	24%	0.146	0.411	282%	0.013	0.032	246%
ECU (lbs/ac)	0.008	0.0	--	0.005	0.011	220%	0.025	0.0	--	0.014	0.011	79%	0.0001	0.002	2000%

[A] Wetfall Station Located on Roof of Burke Village Centre

[B] Wetfall Station Located at Ground Level, Burke Village Centre

[C] Wetfall Station Located at Ground Level, Stedwick site, these percentages are probably typical of the wetfall contribution to runoff phosphorus loadings. At the less impervious residential sites, where rainfall/runoff coefficients would be lower, wetfall total-P loads are 30%-60% of the total runoff load. This is a result of the lower per acre loadings of total-P at the less impervious sites. The contribution of wetfall is probably similar to the shopping center. Organic-P forms are typically 75%-85% of the total-P load.

- Nitrogen forms: Although runoff loads are generally greater than wetfall loads for phosphorus forms, the opposite is true for nitrogen forms where in many cases wetfall loads exceed runoff loads. This may suggest a build-up of nitrogen loadings in the watersheds, however, utilization by vegetation is a more probable explanation. Total kjeldahl nitrogen accounts for 40%-50% of the total-N load.

- Extractable Zinc: Extractable zinc was the only heavy metal for which there was enough data to make wetfall/runoff comparisons. Wetfall is a significant source of zinc loads. Table 27 shows that in all but one case, wetfall loads exceed runoff loads. The relatively lower zinc ratios associated with the roof mounted wetfall sampler suggest that zinc loads might be associated with a source near ground level. Automobile tires, which are commonly named as a source of zinc, would fit this pattern.

Dryfall Analysis

The chemical data in the dryfall datasets was reported by VPI&SU in loading units of mg/m^2, based on the cross-sectional area of the collection buckets. This data was converted to units of lbs/acre. Note that most of this loading data is drawn from samples which typically had durations on the order of 5-7 days and should not be directly compared to runoff loading rates which represent sample durations on the order of 4-12 hours.

The dryfall datasets were also screened for locational and seasonal differences. These results are shown in Tables 28 and 29. Based on the results of one-sided K-S tests a lognormal distribution was assumed for all pollutants. The results in Tables 28 and 29 indicate that there are more locational and seasonal differences in dryfall loadings than were apparent in the wetfall concentration comparisons. Comparisons of dryfall loadings based on the results in Tables 28 and 29 are presented below:

- Total Solids: Haines Point and the Burke ground station exhibit somewhat higher solids loadings. This is probably due to the higher traffic volumes which were in closer proximity to these stations. In terms of seasonality, the winter and spring periods have somewhat higher loading rates than the summer and fall periods.

TABLE 20

DUNCAN'S MULTIPLE RANGE TEST: NURP DRYFALL STATIONS
$\alpha = 0.05$

CONSTITUENT	STATISTIC	BURKE CENTRE -ROOF- (SHPC)	BURKE CENTRE -GROUND- (SHPC)	STEDWICK (THGA)	HAINES PT. (DWTN)	SPRING	SUMMER	FALL	WINTER
TOTAL SOLIDS (lbs/ac)	MEAN MEDIAN DUNCAN GROUPING (N)	2.44 1.02 B (49)	3.87 2.76 A (36)	2.86 1.34 B (27)	5.07 3.94 A (49)	5.31 3.69 A (28)	3.90 2.24 B (50)	1.11 1.80 B (58)	5.11 2.97 A/B (25)
COD (lbs/ac)	MEAN MEDIAN DUNCAN GROUPING (N)	1.12 0.83 B (47)	1.65 1.14 B (37)	0.62 0.46 C (29)	2.78 2.15 A (48)	3.45 2.63 A (25)	1.51 1.10 B (49)	0.99 0.68 C (60)	1.04 1.01 B (27)
TOTAL-P (lbs/ac)	MEAN MEDIAN DUNCAN GROUPING (N)	0.004 0.003 B (47)	0.007 0.004 B (38)	0.004 0.003 B (29)	0.011 0.007 A (49)	0.015 0.010 A (26)	0.008 0.005 B (50)	0.003 0.003 C (61)	0.004 0.003 C (26)
ORTHO-P (lbs/ac)	MEAN MEDIAN DUNCAN GROUPING (N)	0.001 0.001 B (27)	0.004 0.002 A/B (21)	0.002 0.001 A/B (19)	0.005 0.002 A (40)	0.004 0.002 A (20)	0.006 0.002 A (33)	0.002 0.001 A (32)	0.002 0.001 A (22)
TOTAL-N (lbs/ac)	MEAN MEDIAN DUNCAN GROUPING (N)	0.06 0.05 B/C (46)	0.09 0.07 B (30)	0.05 0.05 C (29)	0.13 0.10 A (50)	0.17 0.13 A (25)	0.08 0.06 B/C (50)	0.06 0.05 C (61)	0.09 0.08 B (27)
NITRATE (lbs/ac)	MEAN MEDIAN DUNCAN GROUPING (N)	0.02 0.02 B/C (48)	0.02 0.02 B (38)	0.01 0.01 C (28)	0.04 0.03 A (52)	0.04 0.04 A (27)	0.02 0.02 B (50)	0.02 0.02 B (62)	0.04 0.03 A (28)

TABLE 29

DUNCAN'S MULTIPLE RANGE TEST: NURP DRYFALL STATIONS
α = 0.05

CONSTITUENT	STATISTIC	BURKE CENTRE -ROOF- (SHPC)	BURKE CENTRE -GROUND- (SHPC)	STEDWICK (THGA)	HAINES PT. (DWTN)	SPRING	SUMMER	FALL	WINTER
AMMONIA (lbs/ac)	MEAN MEDIAN DUNCAN GROUPING (N)	0.01 0.01 A (47)	0.02 0.01 A (37)	0.01 0.01 A (29)	0.02 0.01 A (52)	0.02 0.02 A (27)	0.02 0.01 B (49)	0.01 0.01 B (61)	0.02 0.02 A (28)
TKN (lbs/ac)	MEAN MEDIAN DUNCAN GROUPING (N)	0.04 0.03 B/C (47)	0.07 0.05 A/B (38)	0.04 0.04 C (29)	0.09 0.06 A (50)	0.13 0.09 A (26)	0.06 0.04 B (50)	0.03 0.04 B (61)	0.05 0.04 B (27)
EPb (lbs/ac)	MEAN MEDIAN DUNCAN GROUPING (N)	0.008 0.008 A (3)	0.007 0.007 A (2)	0.008 0.008 A (2)	0.009 0.009 A (9)	0.009 0.009 A (2)	0.008 0.008 A (2)	0.008 0.008 A (7)	0.009 0.009 A (5)
EZn (lbs/ac)	MEAN MEDIAN DUNCAN GROUPING (N)	0.004 0.003 B (30)	0.006 0.005 A (32)	0.003 0.003 B (17)	0.006 0.005 A (49)	0.007 0.005 A (18)	0.004 0.004 B (43)	0.004 0.003 B (50)	0.006 0.005 A (25)
ECu (lbs/ac)	MEAN MEDIAN DUNCAN GROUPING (N)	--- --- A (1)	--- --- B (1)	--- --- A/B (1)	0.002 0.002 B (12)	--- --- A (1)	0.005 0.003 A (3)	0.002 0.002 A (3)	0.003 0.002 A (8)

- Chemical Oxygen Demand: Haines Point exhibits the highest mean COD loading rates while Stedwick has significantly lower COD means. COD loading rates at the Burke stations fall in between. This is probably related to the similar pattern noted for the nitrogen forms, particularly nitrate-N and TKN. On a seasonal basis, COD loadings seem to be higher in the spring, lowest in the fall, and at intermediate levels during the summer and winter.

- Phosphorus forms: Mean total and ortho-phosphorus loading rates are somewhat higher at the Haines Point station with very little differences among the other three stations. Total-P loadings are highest in the spring and lowest in the fall and winter periods. Since there is no significant seasonal difference in ortho-P loading rates, organic-P loadings must be exhibiting significant seasonal variations.

- Nitrogen forms: With the exception of ammonia-N, the nitrogen forms exhibit a fairly consistent pattern in terms of locational differences. Haines Point exhibits the highest mean loading rates, Stedwick the lowest, and the Burke Stations intermediate levels. Ammonia-N loading rates are fairly consistent between stations. In terms of seasonal differences, the spring and winter periods are somewhat higher than the summer and fall periods.

- Extractable Zinc: Stations which were near areas of high traffic volume (e.g., Haines Point and the Burke ground station) exhibit somewhat higher EZn loading rates. The summer and fall period exhibit somewhat lower EZn loading rates.

Because dryfall sample durations spanned one or more precipitation events,* no attempt was made to calculate dry weather loading rates (e.g., lbs/ac/day). The durations of the intervening wetfall sample start and end times were not reported and use of the dryfall sample start and end times would over-estimate dryfall sample durations (i.e., since during some unknown period of most dryfall samples, wetfall was being sampled). This would underestimate calculated dry weather loading rates.

V. EFFICIENCY OF POLLUTANT REMOVAL BY MONITORED BMP's

Detention Basin Performance

Introduction. Evaluations of detention basin performance were based upon comparisons of stormwater monitoring data at inflow and outflow stations. It should be emphasized that synoptic data (i.e., complete inflow and outflow data from the same storm event) is required to characterize pollutant removal rates for a given station-storm. In addition, it is important that monitored inflow and outflow volumes be reasonably similar for each storm event to assure a meaningful calculation of pollutant trap efficiency, particularly in the case of dry ponds. For example, a significant number of storms monitored throughout the study period exhibit inflow runoff volumes which are considerably higher than outflow runoff volumes. A calculation of inflow and outflow loads with such monitoring information would result in an overestimate of pollutant removal rates for the storm event because a greater volume of runoff was measured at the inflow station and included in the flow-composite sampling which defined the mean inflow concentration. However, it would not be correct to set the outflow volume equal to the inflow volume and then assign the reported mean outflow concentration to the higher volume, since the flow-composite sampling technique used to develop the mean outflow concentration relied upon a lower runoff volume (and presumably a lower pollutant load).

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*Reported dryfall and wetfall sample start and end times are identical for almost 75% of the samples.

In the case of wet ponds, monitored storms characterized by lower outflow volumes may be acceptable for trap efficiency determinations if excess storage capacity was available in the pond at the start of runoff due to the drawdown of the permanent pool during an extended dry weather period. Determination of whether inflow/outflow differences are acceptable for wet pond station-storms requires a long-term storage-routing study which considers runoff volumes from previous storms and pond evaporation losses between storms. NVPDC developed a storage-routing methodology to characterize long-term removal efficiencies for wet ponds to permit the aggregation of very high trap efficiencies during storms producing little or no outflow (i.e., storms during drought periods) with lower and perhaps negative trap efficiencies during the runoff events which end the low rainfall periods. In other words, it is conceivable that one major benefit of a wet pond is that it can shift the timing of summer nonpoint pollution loadings by: (1) preventing runoff releases from minor-to-moderate storms which occur following pool drawdown and, (2) increasing pollution loadings (i.e., releases of loads accumulated during previous events) from less frequent major storms which terminate pool drawdown and produce overflow. Pollutant loadings from minor-to-moderate storm events can be detained during pool drawdown periods and be degraded by biological processes which can remove dissolved plant nutrient loadings through algal uptake and sinking. Rooted aquatic plants, which were well established at the wet pond sites may provide another mechanism for pollutant removal.

Detention Basin Analysis. The important physical characteristics of the three detention basins are summarized in Table 30. Based on NVPDC's thorough review of the montitoring database, the number of events monitored, and the number of events available for detention basin performance is summarized below:

TABLE 30

DETENTION BASIN CHARACTERISTICS

CHARACTERISTIC	BURKE WET POND	WESTLEIGH WET POND	LAKERIDGE DRY POND
DRAINAGE AREA	27.1 AC.	47.9 AC.	88.4 AC
STORAGE VOLUME			
o PERMANENT POOL	1.3 - 1.4 IN.	1.2 - 1.8 IN.	*
o EMERG. SPILLWAY	4.0 - 4.1 IN.	2.3 - 2.9 IN.	0.5 IN.
SURFACE AREA			
o PERMANENT POOL	0.92 AC.	1.17 AC.	*
o EMERG. SPILLWAY	1.44 AC.	1.54 AC.	1.2 AC.
MEAN DEPTH			
o PERMANENT POOL	3.3 - 3.5 FT.	4.2 - 6.1 FT.	*
o EMERG. SPILLWAY	6.3 - 6.4 FT.	6.1 - 7.6 FT.	3.1 FT.

SITE	BMP	# OF STORMS MONITORED	# OF SYNOPTIC EVENTS	# OF ACCEPTABLE SYNOPTIC EVENTS
Burke Ponds				
Inflow	Wet Pond	60	29	13
Outflow		33		
Westleigh				
Inflow	Wet Pond	41	29	16
Outflow		45		
Lakeridge				
Inflow	Dry Pond	49	28	16
Outflow		41		
Stedwick				
Inflow	Dry Pond	47	25	0
Outflow		33		

Of the 349 total events monitored, 111 pairs are synoptic (e.g., 222 events or 64% of the total number monitored). Of the 111 synoptic pairs, only 45 (e.g., 41% of the synoptic events) are acceptable. The remaining 66 synoptic pairs are characterized by other problems such as significant differences (e.g., greater than 30%) between inflow and outflow volumes. Table 31 shows a listing of inflow and outflow runoff volumes and pollutant loadings for the 45 acceptable synoptic events at the four detention basin monitoring sites. The pollutant removal rates for each storm event are summarized in Table 32. Presented below are comments on the synoptic storms at each site.

- Stedwick Dry Pond: This is the only dry pond with the relatively high design detention times advocated in "Guidebook for Screening Urban Nonpoint Pollution Management Strategies" (1). Unfortunately the pond did not perform as designed. A site visit, conducted in April, 1982 (i.e., after the monitoring station had been dismantled) during a medium sized precipitation event (e.g., approximately 0.5 inch) gave evidence to this effect. The pond was completely emptied in approximately 6 hours. Rough calculations show that the release rate is approximately 5 times the design release rate for higher pool elevations and approximately 2 times the design release rate for lower pool elevations. A leak was noted at the base of the riser. It is felt that this pond's performance is more typical of a peak shaving stormwater management pond (e.g., similar to Lakeridge) and that it would offer no new insights into BMP performance. There were also serious problems achieving consistent flow measurements at this site. Much of the spurious flow data is believed to be a result of the close proximity of high voltage power lines as the basin is located in a utility right of way.

TABLE 31-A

NURP DETENTION BASIN BMP INFLOW/OUFLOW LOACS (lbs/acre)

NAME=BURKE PONC

STRDATE	STRMNO	ILDTSS	CLDTSS	ILDCOD	OLDCOD	ILDTF	OLGTP	ILDTSP	OLGTSP	ILDOF	OLGOP
19FEB81	416	1.732	1.513	3.364	2.724	.08466	.0C434	.08333	.0C227	.03228	.00074
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
05APR81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.00366	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
14APR81	470	[illegible]	[illegible]	[illegible]	[illegible]	.	[illegible]	[illegible]	[illegible]	[illegible]	.0C000
19MAY81	505	[illegible]	[illegible]	[illegible]	[illegible]	.00313	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
02JUN81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.00190	[illegible]
25JUN81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.	[illegible]
04JUL81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.C1618	[illegible]
24JUL81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11AUG81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15AUG81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30AUG81	608	1.287	[illegible]	1.000	[illegible]	.01969	[illegible]	[illegible]	[illegible]	[illegible]	.00000
01OCT81	640	0.194	0.143	0.762	0.382	.00427	.0C207	.00349	.00078	.00271	.00026

NAME=LAKE RIDGE

STRDATE	STRMNO	ILDTSS	OLDTSS	ILDCOD	OLDCOD	ILDTP	OLCTP	ILDTSP	OLDTSP	ILDOP	OLDOP
23OCT80	299.0	69.930	20.293	3.442	2.424	.08524	.04742	.02657	.	.02857	.02978
21NOV80	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.00272	.00143	[illegible]	.00044	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	X	X	.00014	[illegible]	[illegible]	.00027
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.03773	.02340	.	[illegible]	[illegible]	.
03APR81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.00038	.00041	[illegible]	.00010
12APR81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.0C190	[illegible]	[illegible]
15APR81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.00284	.0C055	[illegible]	[illegible]	.00060	.00006
17APR81	[illegible]	[illegible]	[illegible]	0.802	[illegible]	X	X	[illegible]	[illegible]	X	X
[illegible]	[illegible]	[illegible]	[illegible]	.	[illegible]	.00064	.00034	[illegible]	[illegible]	[illegible]	.00005
30APR81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.00013	.00009	.C00C5	.00004
11MAY81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	X	X	X	X
10JUN81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.0C511	X	X	.00017	.00020
13JUN81	530.0	[illegible]	[illegible]	[illegible]	[illegible]	.01250	.02502	X	X	[illegible]	.00142
25JUN81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	X	X	.00239	.00607	X	X
04JUL81	551.0	20.705	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	X	X
03AUG81	561.0	1.640	1.145	0.730	0.474	.00601	.0C487	.00129	.00108	.C01C3	.00081

NAME=WESTLEIGH

STRDATE	STRMNO	ILDTSS	OLGTSS	ILDCOD	OLDCOD	ILDTP	OLCTP	ILDTSP	OLDTSP	ILDOP	CLOOP
23FEB81	420	7.187	1.491	3.398	1.844	.03069	.01153	.02149	.00538	.01878	.00231
11APR81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.00032
15APR81	470	[illegible]	[illegible]	[illegible]	0.785	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.00008
[illegible]	504	[illegible]	[illegible]	[illegible]	.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.00000
03JUN81	520	[illegible]	[illegible]	[illegible]	0.105	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.0C000
06JUN81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.00003
10JUN81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.0C007
13JUN81	530	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
06AUG81	[illegible]	[illegible]	[illegible]	[illegible]	0.218	[illegible]	.0C161	[illegible]	[illegible]	[illegible]	.00011
08AUG81	[illegible]	[illegible]	[illegible]	[illegible]	.	[illegible]	.	[illegible]	[illegible]	[illegible]	.0C005
[illegible]	608	[illegible]	[illegible]	[illegible]	1.530	[illegible]	.0C473	[illegible]	[illegible]	[illegible]	[illegible]
08SEP81	617	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.0C001
08SEP81	617	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.0C001
18OCT81	657	0.369	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
06NOV81	676	0.230	0.0C7	0.232	0.125	.00344	.0C025	.00293	.00022	.00257	.00004

STRDATE = Date of storm
STRMNO = Storm number
ILDTSS = Total Suspended Solids Inflow Load (lbs/acre)
ILDTP = Total Phorphorus Inflow Load (lbs/acre)
ILDDP = Total Dissolved P Inflow Load (lbs/acre)
ILDPO4 = Ortho-phosphorus Inflow Load (lbs/acre)
ILDTN = Total Nitrogen Inflow Load (lbs/acre)
ILDTKN = Total Kjeldahl Nitrogen Inflow Load(lbs/acre
ILDTSN = Total Dissolved Nitrogen Inflow Load (lbs/acre)
ILDNH3 = Ammonia Nitrogen Inflow Load (lbs/acre)
ILDNO23 = Nitrate + Nitrite N Inflow Load (lbs/acre)
ILDEZN = Extractable Zinc Inflow Load (lbs/acre)
ILDSZN = Soluble Zinc Inflow Load (lbs/acre)

OLDTSS = Total Suspended Solids Outflow Load (lbs/acre)
OLDTP = Total Phorphorus Outflow Load (lbs/acre)
OLDDP = Total Dissolved P Outflow Load (lbs/acre)
OLDPO4 = Ortho-phosphorus Outflow Load (lbs/acre)
OLDTN = Total Nitrogen Outflow Load (lbs/acre)
OLDTKN = Total Kjeldahl Nitrogen Outflow Load(lbs/acre
OLDTSN = Total Dissolved Nitrogen Outflow Load (lbs/acre)
OLDNH3 = Ammonia Nitrogen Outflow Load (lbs/acre)
OLDNO23 = Nitrate + Nitrite N Outflow Load (lbs/acre)
OLDEZN = Extractable Zinc Outflow Load (lbs/acre)
OLDSZN = Soluble Zinc Outflow Load (lbs/acre)

NOTE: X = Inconsistent value set equal to 0.0

TABLE 31-8

NURP DETENTION BSIN BMP INFLOW/OUTFLOW LOADS (lbs/acre)

NAME=BURKE POND

STRDATE	STRMNO	ILOTN	OLOTN	ILOTSN	OLOTSN	ILONO23	OLONO23	ILONH3	OLONH3	ILOTKN	OLOTKN	ILOEZN	OLOEZN	ILDSZN	OLDSZN
19FEB81	[illegible]	0.144	0.088	0.147	0.074	0.089	0.018	0.011	0.012	0.074	0.070	.	0.000	.	.
22FEB81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.000	0.000
05APR81	[illegible]	0.670	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.059	[illegible]	[illegible]	[illegible]	0.460	[illegible]
15APR81	[illegible]	.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.	[illegible]	[illegible]	[illegible]	.	[illegible]
19MAY81	[illegible]	0.045	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.033	[illegible]	[illegible]	[illegible]	0.627	[illegible]
02JUN81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
25JUN81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
05JUL81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
24JUL81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11AUG81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
13AUG81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30AUG81	[illegible]	0.125	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.101	3.108	1.304	[illegible]	0.000
01OCT81	640	0.342	0.023	0.036	0.012	0.013	0.001	0.006	0.002	0.029	0.022	0.000	0.000	.	0.000

NAME=LAKE RIDGE

STRDATE	STRMNO	ILOTN	OLOTN	ILOTSN	OLOTSN	ILONO23	OLONO23	ILONH3	OLONH3	ILOTKN	OLOTKN	ILOEZN	OLOEZN	ILDSZN	OLDSZN
23OCT80	299.0	0.301	0.219	0.242	0.180	0.132	0.104	0.056	0.047	0.146	0.114	0.143	4.411	4.762	2.206
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.222
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.040	[illegible]
09APR81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.	0.000
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.095	0.000
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.	0.000
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.	0.097
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.133	0.065
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.010	[illegible]	0.007	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	X	X	X	X	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	X	X	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	X	X	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.188
04JUL81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.053	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.
03AUG81	[illegible]	0.034	0.050	0.018	0.017	0.009	0.010	0.002	0.001	0.025	0.020	1.374	0.721	0.816	0.586

NAME=WESTLEIGH

STRDATE	STRMNO	ILOTN	OLOTN	ILOTSN	CLOTSN	ILONO23	OLONO23	ILONH3	OLONH3	ILOTKN	OLOTKN	ILOEZN	OLOEZN	ILDSZN	OLDSZN
23FEB81	[illegible]	0.213	0.147	0.199	0.122	0.045	0.037	0.043	0.037	0.170	0.110	.	0.000	.	.
11APR81	[illegible]	[illegible]	[illegible]	.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.	0.000	.	0.000
14APR81	[illegible]	[illegible]	0.029	0.036	0.022	[illegible]	[illegible]	0.004	[illegible]	[illegible]	0.021	0.743	0.313	0.373	0.313
15MAY81	[illegible]	[illegible]	.	[illegible]	.	[illegible]	[illegible]	.	[illegible]	[illegible]	.	[illegible]	.	[illegible]	.
18MAY81	[illegible]	[illegible]	0.002	[illegible]	0.002	[illegible]	[illegible]	0.002	[illegible]	[illegible]	0.002	[illegible]	0.281	.	.
03JUN81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.363	.
06JUN81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.	0.117
10JUN81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.	[illegible]
13JUN81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.303	[illegible]
06AUG81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.015	[illegible]	0.429	[illegible]	0.134
08AUG81	[illegible]	[illegible]	.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.	0.221	.	.	.
10AUG81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.	0.000	.	0.000
08SEP81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.241	.	0.145	0.000
09SEP81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.	[illegible]	0.000
18OCT81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.	0.000	.
08NOV81	[illegible]	0.029	0.004	0.024	0.005	0.005	0.001	0.009	0.001	0.024	0.005	0.000	0.000	.	0.000

STRDATE = Date of storm
STRMNO = Storm number
ILOTSS = Total Suspended Solids Inflow Load (lbs/acre)
ILOTP = Total Phosphorus Inflow Load (lbs/acre)
ILODP = Total Dissolved P Inflow Load (lbs/acre)
ILOPO4 = Ortho-phosphorus Inflow Load (lbs/acre)
ILOTN = Total Nitrogen Inflow Load (lbs/acre)
ILOTKN = Total Kjeldahl Nitrogen Inflow Load(lbs/acre
ILOTSN = Total Dissolved Nitrogen Inflow Load (lbs/acre)
ILONH3 = Ammonia Nitrogen Inflow Load (lbs/acre)
ILONO23 = Nitrate + Nitrite N Inflow Load (lbs/acre)
ILOEZN = Extractable Zinc Inflow Load (lbs/acre)
ILDSZN = Soluble Zinc Inflow Load (lbs/acre)

OLOTSS = Total Suspended Solids Outflow Load (lbs/acre)
OLOTP = Total Phosphorus Outflow Load (lbs/acre)
OLODP = Total Dissolved P Outflow Load (lbs/acre)
OLOPO4 = Ortho-phosphorus Outflow Load (lbs/acre)
OLOTN = Total Nitrogen Outflow Load (lbs/acre)
OLOTKN = Total Kjeldahl Nitrogen Outflow Load(lbs/acre
OLOTSN = Total Dissolved Nitrogen Outflow Load (lbs/acre)
OLONH3 = Ammonia Nitrogen Outflow Load (lbs/acre)
OLONO23 = Nitrate + Nitrite N Outflow Load (lbs/acre)
OLOEZN = Extractable Zinc Outflow Load (lbs/acre)
OLDSZN = Soluble Zinc Outflow Load (lbs/acre)

NOTE: X = Inconsistent value set equal to 0.0

A cleanout of the Stedwick dry pond was conducted approximately two years after the basin was retrofit with a perforated riser. Significant accumulation of sediment, litter and debris had occurred at this time. A layer of material approximately 8 to 10 inches deep had accumulated in the vicinity of the riser. Core samples taken from the surface soils in this area indicated that significant accumulation of trace metals had occurred due to stormwater infiltration. Therefore, while the data from this site could not be used to quantify pollutant removal efficiencies, there is strong evidence that pollutant removal did occur, and, that properly designed and constructed, the high detention time dry pond can be an effective BMP.

- Lake Ridge Dry Pond: Only 28 out of a total of 48 monitored runoff events (excluding storms prior to October 25, 1980 due to flow-gaging problems) are synoptic. Of this total, sixteen storms are characterized by outflow volumes within at least 70% of the inflow volumes and therefore are considered acceptable for analyses of detention basin performance.

- Burke Ponds Wet Pond: Of the 29 synoptic runoff events, thirteen storms are considered acceptable for pollutant removal analysis. Ten storms were accepted for analysis on the basis that the sum of measured outflow volume plus estimated unfilled capacity was within 80% of the adjusted inflow volume (i.e., the inflow volume is adjusted to reflect ungaged local inflow).

- Westleigh Wet Pond: Of the 29 synoptic runoff events, sixteen storms are considered to be acceptable for pollutant removal analysis. Ten storms were accepted for analysis on the basis that the sum of measured outflow volume plus estimated unfilled capacity was within 80% of the adjusted inflow volume.

For the 29 acceptable synoptic storms, calculated pollutant removal efficiencies for wet ponds were normalized by the ratio of inflow to outflow volumes. This is required because of the significant differences between inflow and outflow runoff volumes for many storm events which are due to drawdown of the wet pond prior to the storm. Unless the ratios of inflow and outflow loads are adjusted to account for these differences, pollutant removal calculations will be biased by the relationship of inflow and outflow volumes (i.e., pollutant removal efficiencies will be overestimated for storms where inflow volume is greater than outflow volume, and underestimated for storms where outflow volume is greater than inflow volume.) To normalize the pollutant removal rate for wet ponds to account for water balance errors, the following relationship was used:

$$\text{Pollutant Removal Efficiency (\%)} = (100\%)(1.0-((P_{OUT}/P_{IN})/(V_{OUT}/V_{IN})))$$

where P_{OUT} = Outflow Pollutant Load
P_{IN} = Inflow Pollutant Load
V_{OUT} = Outflow Volume
V_{IN} = Inflow Volume

The adjusted pollutant removal efficiencies for detention ponds are presented in Table 32.

In deriving the pollutant removal rates shown in Table 32, monitored inflow volumes and loads were adjusted to reflect direct inflows to the detention basin from land area between the inflow and outflow monitoring stations. The monitored inflow volumes were increased by the ratio of drainage areas (i.e., ungaged drainage area/inflow station drainage area) adjusted by the ratios of runoff coefficients to produce a total inflow volume for the detention basin. Drainage areas are presented in Table 1. A runoff coefficient of 0.9 was assumed for impervious areas, and for pervious areas, 0.2 was assumed. Based on these computations, Burke Pond inflows were adjusted upward by 1.338, and Westleigh inflows were adjusted upward by 1.242. The total inflow load for the detention basin was then based on the product of the total inflow volume and the monitored inflow event mean concentration.

Likewise, excess storage capacity in the wet ponds at the start of a storm event was included in the outflow volume used to calculate the water balance correction factor described above. Software was developed to conduct a mass balance on the inflow and outflow hydrographs so that the cumulative volume of runoff stored in the pond after any time step could be estimated. These analyses also facilitated detection of timing and gaging problems. Based upon these storage-routing studies for the wet pond, excess storage capacity was set equal to the cumulative total inflow volume prior to the start of outflow. By adjusting the outflow volume and water balance correction factor to reflect the storage of runoff due to drawdown of the permanent pool caused by evaporation losses, the wet pond removal rates are not penalized because of differences between inflow and outflow volumes. This is an appropriate correction for wet pond data, since it is quite likely that the differences between inflow and outflow volumes reflect the actual performance of the prototype rather than flow-gaging errors.

One final correction presented in Table 32 merits elaboration. The dry pond data was screened to check the consistency of calculated removal rates for suspended and dissolved pollutants. Inconsistent data is flagged with an "X" and treated as a missing value. Examples of inconsistencies which were flagged in this manner include:

- A storm event with a positive removal rate for a nitrogen or phosphorus fraction and a negative or zero removal rate for total N or total P.

- A storm event with a positive removal rate for total N or total P and a negative or zero removal rate for TSS and dissolved nitrogen (TSN) or dissolved phosphorus (TSP). Since no removal of TSS occurred, a positive removal rate for suspended N or P is inconsistent.

TABLE 32
NURP DETENTION BASIN BMP REMOVAL EFFICIENCIES (%)

NAME=BLAKE POND

STRDATE	STRMNO	PCTTSS	PCTCOD	PCTTP	PCTTSP	PCTPO4	PCTTN	PCTNO23	PCTNH3	PCTTKN	PCTTSN	PCTEZN	PCTSZN
19FEB81	416	6.7	11.6	94.3	97.1	97.5	43.0	78.3	-16.3	2.3	44.9	.	.
[illegible]FEB81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.	.
05APR81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-12.4	100.0
13APR81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.	.
09MAY81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	82.6	0.0
02JUN81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	100.0	.
[illegible]JUN81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	29.0	.
04JUL81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	100.0	.
24JUL81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-102.9	100.0
11AUG81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	100.0	.
15AUG81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	58.7	.
30AUG81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.	.
01OCT81	240	16.4	42.9	44.7	74.7	89.1	36.9	87.7	56.2	15.8	65.3	.	.

NAME=LAKE RIDGE

STRDATE	STRMNO	PCTTSS	PCTCOD	PCTTP	PCTTSP	PCTPO4	PCTTN	PCTNO23	PCTNH3	PCTTKN	PCTTSN	PCTEZN	PCTSZN
25OCT80	299.0	64.2	65.0	38.6	.	-28.6	10.0	3.1	-7.5	15.3	8.4	33.3	42.9
[illegible]NOV80	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]FEB81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]FEB81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
09APR81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12APR81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
14APR81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]APR81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]APR81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30APR81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11MAY81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]JUN81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]JUN81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]JUN81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]JUL81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
03AUG81	381.0	33.5	38.1	22.9	20.0	25.0	16.6	-3.9	42.9	23.1	5.4	50.0	31.6

NAME=WESTLEIGH

STRDATE	STRMNO	PCTTSS	PCTCOD	PCTTP	PCTTSP	PCTPO4	PCTTN	PCTNO23	PCTNH3	PCTTKN	PCTTSN	PCTEZN	PCTSZN
23FEB81	420	65.2	48.4	44.4	62.9	81.8	-1.3	-21.5	13.6	6.1	9.0	.	.
11APR81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
14APR81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15MAY81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
18MAY81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
03JUN81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
06JUN81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10JUN81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
13JUN81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
06AUG81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
08AUG81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30AUG81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
08SEP81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
08SEP81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
18OCT81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
06NOV81	276	97.3	80.7	94.6	94.6	99.0	83.7	81.3	90.7	84.2	84.0	100.0	.

STRDATE = Date of storm
STRMNO = Storm number
INVOL = Inflow Volume (inches)
OUTVOL = Outflow volume (inches)
PCTTSS = Total Suspended Solids Removal (%)
PCTTP = Total Phosphorus Removal (%)
PCTTSP = Total Dissolved P Removal (%)
PCTPO4 = Ortho-phosphorus Removal (%)
PCTTN = Total Nitrogen Removal (%)
PCTTKN = Total Kjeldahl Nitrogen Removal(%)
PCTTSN = Total Dissolved Nitrogen Removal (%)
PCTNH3 = Ammonia Nitrogen Removal (%)
PCTNO23 = Nitrate + Nitrite N Removal (%)
PCTEZN = Extractable Zinc Removal (%)
PCTSZN = Soluble Zinc Removal (%)

NOTE: X = Inconsistent value set equal to 0.0

Detention basin comparisons based upon the summary of pollutant removal rates shown in Table 32 are presented below. Throughout the discussion, reference is made to a "typical" range of removal rates. It should be noted that this reported range is intended to provide an indication of the range of positive removal rates observed most frequently, rather than absolute upper and lower limits of removal rates at each site. It is felt that discussions of "typical" ranges of removal rates can provide considerable insight into the trends at each BMP site.

Burke Ponds

- Storm Events: A total of 13 synoptic storms are available for pollutant removal analyses at this wet pond site. Six of these storms produced significant runoff volumes on the order of 0.2 in or higher and 5 events were characterized by runoff volumes in the range 0.10-0.19 in.

- Total Suspended Solids: TSS removal rates were negative* or close to zero for 4 storm events. TSS removal rates for the other storm events were typically on the order of 40%-70%.

- Chemical Oxygen Demand: COD removal rates for most events were typically on the order of 45%-85%. Negative removal rates were identified for 4 storm events.

- Phosphorus: Total P removal rates were typically on the order of 55%-85%. Negative or zero total P removal rates were identified for 2 storm events. It is also interesting to note that the February 22, 1981 runoff event which produced a very high runoff volume (1.2 in) was characterized by a relatively low total P removal rate, suggesting that some of the loads which accumulated in the wet pond during the 1980-1981 drought may have been flushed out by this rainstorm. Total dissolved P (TSP) removal rates were higher than total P removal rates for most storm events, with values typically on the order of 40%-90%. Likewise, ortho-P removal rates were relatively high, with most values greater than removal rates for TSP and on the order of 60%-99%. These relatively high removal rates for dissolved plant nutrient loadings suggest that algae, wetland vegetation, and bottom sediments are achieving relatively high levels of phosphorus removal. These high removal rates for TSP and ortho-P are particularly notable since dissolved phosphorus forms are most readily available for biological activity (i.e., algal growth).

- Nitrogen: Total N removal rates were typically lower than total P removal rates, with typical values on the order of 30%-55%. Negative total N removal rates were noted for two storms. Total dissolved N (TSN) removal rates were typically slightly higher than total N removal, due to relatively high nitrate N removal rates for most storms (e.g., nitrate removals were greater than 60% for 8 storm events). TKN removal rates were usually lower than total N removal rates, with the lowest and negative TKN rates occurring during relatively high runoff events that probably flushed out a significant amount of the organic materials in the wet pond prior to the storm. The relatively low and often negative removal rates for ammonia N are probably indicative of significant levels of ammonification (i.e., conversion of organic N to ammonia N) within the wet pond between storm events.

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*A negative removal rate indicates that the calculated pollutant load released from the detention basin was greater than the inflow load.

- Zinc: Extractable zinc removal rates were typically on the order of 60%-100%. Negative removal rates were identified for two storms.

Lake Ridge

- Storm Events: A total of 16 synoptic storms are available for pollutant removal analyses at this dry pond which is designed for peak-shaving purposes. Eight of these storms produced significant runoff volumes, with 3 events characterized by runoff volumes on the order of 0.45-0.9 in and 5 events characterized by runoff volumes on the order of 0.10-0.15 in. Eight storms where characterized by runoff volumes less than 0.045 in.

- Total Suspended Solids: TSS removal rates were negative or close to zero for 10 storms. Removal rates for the other storm events were typically on the order of 25%-45%.

- Chemical Oxygen Demand: COD removal rates were negative or zero for 6 storms. Removal rates for other storms were typically on the order of 25%-45%.

- Phosphorus: Total P removal rates were negative or zero for 10 storms, with four of those storms characterized by significant runoff volumes. Total P removal rates for other storms which produced more than 0.1 in of runoff were typically on the order of 20%-40%. Total dissolved P (TSP) removal rates were negative or zero for 11 storms, and were 20%-25% for three other minor storms with TSP data. Ortho-P removal rates were negative or zero for 12 storms, with only two minor storms characterized by positive removal rates. The poor performance of the Lake Ridge dry pond for TSP and ortho-P removal is not unexpected since the principal removal mechanism in a dry pond is sedimentation of suspended pollutants.

- Nitrogen: Total N removal rates were negative or zero for 6 storms, and typically somewhat lower than total P removal rates for other storms. Total dissolved N (TSN) removal rates were typically slightly lower than total N removal rates, as were removal rates for nitrate N and ammonia N. Removal rates for TKN were typically higher than total N removal rates, due in large part to the higher suspended fraction of TKN.

- Zinc: Extractable zinc removal rates were negative or zero for 7 storms, most of which were characterized by high runoff volumes. Removal rates were typically 50%-70% for 5 other storms, most of which were characterized by relatively low runoff volumes. It is conceivable that the relatively high removals during low runoff events can be attributed to adsorption onto the dry ponds bottom sediments which may have been enhanced by a very low ponding level and a relatively high travel time through the basin.

Westleigh

- Storm Events: A total of 16 storms are available for pollutant removal analysis at the Westleigh wet pond. Five of these storms produced significant runoff volumes, with 3 events characterized by volumes on the order of 0.15 in or higher and 2 events characterized by volumes on the order of 0.08 in. Eleven storms produced runoff volumes less than 0.05 in.

- Total Suspended Solids: TSS removal rates were typically on the order of 65%-95%. Only one storm event exhibited negative removal rates.

- Chemical Oxygen Demand: COD removal rates were typically on the order of 45%-80%. Negative removal rates were identified for two storm events.

- Phosphorus: Total P removal rates were typically on the order of 40%-80%, with negative removals evident for only one storm event. Total dissolved P (TSP) removal rates were typically on the order of 55%-85%, while ortho-P removal rates were typically even higher (80%-100%). These relatively high removal rates for dissolved phosphorus forms are consistent with the monitoring results at Burke Ponds. These results tend to confirm the effectiveness of biological and perhaps chemical processes in wet ponds.

- Nitrogen: Total N removal rates were typically somewhat lower than total P removal rates, with negative values identified for 4 storms and removal rates for the remaining storms typically on the order of 40%-70%. Total dissolved N (TSN) removal rates were typically on the order of 30%-65%, while removal rates for ammonia N and particularly nitrate N were typically somewhat higher. As was the case at Burke Ponds, TKN removal rates were often lower than total N removal rates.

- Zinc: Extractable zinc data is available for only five storm events. Two of these storms exhibited negative removal rates, while three exhibited removal rates on the order of 65%-100%.

Wet Pond vs. Dry Pond Performance

A qualitative comparison of the pollutant removal efficiencies noted at the wet ponds versus the dry pond is presented below:

- Total Suspended Solids: TSS removal rates were highest at the two wet ponds (i.e., typically on the order of 40%-95%) and lowest at the Lake Ridge dry pond (i.e., negative for more than half the storms and 20%-65% for the others). At the wet ponds and the Lake Ridge dry pond, negative or low removal rates were identified during some of the storms characterized by relatively high runoff volumes.

- Chemical Oxygen Demand: COD removal rates were highest at the two wet ponds (i.e., typically on the order of 45%-85%) and lowest at the Lake Ridge dry pond (i.e., 25%-45%). In general, COD removal rates appeared to be related to TSS removal rates, with negative COD removal rates often occurring during storms with negative TSS removal rates.

- Total Phosphorus: Total P removal rates were highest at the two wet ponds (i.e., 55%-80%), and lowest at the Lake Ridge dry pond (i.e., negative or zero for almost two-thirds of the storms and 20%-40% for the most significant remaining storms). The mean suspended P fraction for inflows to the Lake Ridge dry pond was approximately 80% for the four storm events which produced non-negative total P removal rates. As previously suggested, the much higher suspended P fractions at the Lake Ridge site may be due to the use of sequential discrete sampling techniques which may have resulted in an overestimate of sediment-related loadings. Since sedimentation is expected to be the principal pollutant removal mechanism at a dry pond, an overestimate of suspended loadings at Lake Ridge would be expected to produce a similar overestimate of pollutant removal rates, since the significance of dissolved loadings would be underestimated.

- Dissolved Phosphorus: Removal rates for total dissolved phosphorus (TSP) and ortho-P were highest at the two wet ponds (i.e., 40%-90% for TSP and 60%-99% for ortho-P) and lowest at the Lake Ridge dry pond (i.e., negative or zero for two-thirds of the storms in the case of TSP and three-fourths of the storms in the case of ortho-P).

- Total Nitrogen: Total N removal rates were typically lower than total P removal rates at most monitoring sites. Removal rates were highest at the two wet ponds (i.e., 30%-70%) and lowest at the Lake Ridge dry pond (i.e., 5%-30%).

- Dissolved Nitrogen: TSN removal rates were highest at the two wet ponds (i.e., 30%-60%) and lowest at the Lake Ridge dry pond (i.e., 7%-25%). Nitrate N removal rates were highest at the two wet ponds (i.e., typically greater than 60%) and lowest at the Lake Ridge dry pond (i.e., negative removal rates for 9 storms). Ammonia N comparisons are similar to the nitrate N comparisons.

- Zinc: Extractable zinc removal rates are typically higher at the two wet ponds (i.e., 60%-100%) for storms with non-negative values) than at the two dry ponds.

In summary, a comparison of the detention basin BMP data indicates that the most effective measure is a wet pond, due in large part to the availability of biological and chemical mechanisms which can remove dissolved pollutants. The least effective measure is a dry pond designed to achieve peak-shaving purposes. Unfortunately there was no representative data available on the multipurpose dry pond designed to achieve relatively high detention times for a nonpoint pollution management pool. The analyses presented herein suggest that the optimal stormwater detention BMP may be a wet pond with high detention times for a portion of storage set aside for nonpoint pollution management. The wet pond elements would provide the biological and chemical removal mechanisms required to enhance the removal of dissolved pollutants, while the high detention times (i.e., increased storage) achieved by a nonpoint pollution management pool should enhance sedimentation and increase opportunities for biological and chemical removal of dissolved pollutants

Statistical Analyses of Wet Pond Performance

The above discussion is primarily limited to qualitative assessments of detention basin performance. In order to quantitatively assess performance characteristics, mean pollutant removal efficiencies (%) were calculated for the individual sites and the two wet ponds pooled. Both volume weighted and arithmetic means are presented in Table 33. Since the storms included in the detention basin analyses are representative of a variety of hydrometeorologic conditions over the duration of the monitoring period, it is reasonable to compare these observed removal efficiencies to the average annual pollutant removal rates projected as a result of 208 modeling studies (1). Comparisons are summarized below:

- Total Suspended Solids: Model projections had estimated wet pond sediment removal to be 88%-89%. Actual performance approached this for many events; however, the mean sediment removal was about 17%-23%. This is felt to be a direct result of the much lower sediment loadings characterizing the NURP datasets. For short detention (peak shaving) ponds, model projections suggested very low sediment removal rates. At the Lakeridge dry pond site, mean sediment trap efficiencies were negative 70%. This may be due to channel scour.

- Phosphorus Forms: Wet pond model projections had conservatively assumed phosphorus removal by sedimentation only. For wet ponds, total-P removal rates were estimated to be 33%-40% with no removal

TABLE 33

MEAN % REMOVAL OF POLLUTANT LOAD AT WET AND DRY POND BMP SITES

CONSTITUENT	BURKE (WET POND)			WESTLEIGH (WET POND)			LAKERIDGE (DRY POND)			POOLED WET PONDS		
	N	VOLUME WEIGHTED MEAN	MEAN	N	VOLUME WEIGHTED MEAN	MEAN	N	VOLUME WEIGHTED MEAN	MEAN	N	VOLUME WEIGHTED MEAN	MEAN
TSS	13	1.2	-27.2	16	62.0	60.5	16	-51.2	-70.1	29	17.3	23.0
COD	13	-58.8	34.4	13	33.3	52.2	14	-22.0	16.6	26	-35.5	19.7
TOTAL-P	12	41.5	42.2	15	44.8	43.2	16	-4.6	-3.0	27	42.4	43.3
TSP	13	53.3	46.0	16	68.4	72.4	14	-10.0	-13.8	29	57.3	62.3
ORTHO-P	12	65.3	65.9	15	88.9	92.7	10	-20.6	-12.5	27	71.5	84.2
TOTAL-N	12	17.4	35.4	14	4.5	30.0	16	-5.3	-1.1	26	14.0	30.4
NITRATE	13	58.1	66.2	16	22.2	45.8	16	-5.7	-3.3	29	48.6	57.1
AMMONIA	13	-25.3	-22.5	15	25.1	44.1	16	19.9	5.6	28	-12.2	12.9
TKN	12	-0.6	14.3	14	-8.4	11.8	16	-3.9	-0.7	26	-2.6	12.8
TSN	13	18.5	35.0	14	25.9	44.8	16	-1.2	2.6	27	20.2	40.0
EZN	8	74.3	80.4	6	51.2	68.8	15	-56.3	-8.9	14	71.2	75.5
SZN	3	51.4	59.1	5	53.0	17.0	10	25.6	-36.8	8	52.1	7.4

of dissolved or inorganic-P. The results of the wet pond analysis show total-P removal rates to be slightly higher, (43% removal) with significant removal of dissolved and ortho-P at 62% and 84%, respectively. As previously mentioned, this is believed to be due to biological and chemical processes occurring in the littoral and limnetic zones of these ponds. Phosphorus removal was estimated to be about 10% in peak shaving facilities. At Lakeridge, slightly negative mean removal rates were observed for total-P (-3%), dissolved-P (-14.0%) and ortho-P (-13%).

- Nitrogen Forms: Total-N and TKN removal rates were projected to be 21%-35% and 25%-42%, respectively. Actual total-N removal rates were about 30%. While TKN removal rates were somewhat lower at 13% due to the higher suspended fraction of TKN, approximately 40% of the soluble-N was removed. This result is analagous to the soluble-P findings discussed above. The dry pond exhibited slightly negative removal rates for all nitrogen forms except ammonia-N.

- Zinc Forms: Model projections estimated annual zinc removal to be 44%-50% for wet ponds. Actual performance was significantly higher at 71%

Wet Pond Pollutant Removal Regression Models

Linear regression models were developed for the wet pond pollutant removal data. A stepwise regression technique (6) was used to determine the best one, two, or three variable model to describe pollutant removal efficiencies. An initial exploratory analysis was performed to correlate watershed characteristics including drainage area, permanent pool storage volume, and percent imperviousness, to pollutant removal efficiencies. These analyses yielded very poor correlations and most of the independent variables exhibited F-statistics which were not significant at the 0.05 significance level. Good correlations were found between pollutant removal efficiencies and (1) storm event inflow volumes (inches), (2) storm event outflow volumes, and (3) inflow event mean concentrations. The general model used, regression coefficients, R^2, and the standard error of the estimate are summarized in Table 34. The general model presented in Table 34 is transformed from the logarithmic form given below:

$$\ln(\text{REMOVAL } \%) = 100 - [a_* + b_1 \ln(Q_{in}) + b_2 \ln(Q_{out}) + b_3 \ln(C_{in})]$$

Where $a_* = \ln a_1$

b_1, b_2, b_3 = regression coefficients

Q_{in} = inflow volume (inches)

Q_{out} = outflow volume (inches)

C_{in} = inflow mean concentration (mg/L)

TABLE 34

WET POND POLLUTANT REMOVAL: MULTIPLE REGRESSION MODELS

GENERAL MODEL:

$$\text{REMOVAL } (\%) = 100 - [a_1(Q_{in})^{b_1} * (Q_{out})^{b_2} * (C_{in})^{b_3}]$$

WHERE

$$\text{REMOVAL } (\%) = \left(1 - \frac{\text{OUTFLOW LOAD (lbs/ac)}}{\text{INFLOW LOAD (lbs/ac)}}\right) * 100$$

Q_{in} = INFLOW RUNOFF (INCHES)

Q_{out} = OUTFLOW RUNOFF (INCHES)

C_{in} = INFLOW MEAN POLLUTANT CONCENTRATION (mg/L)

a_1, b_1, b_2, b_3 = REGRESSION COEFFICIENTS

RESULTS:

CONSTITUENT	N_{EVENTS}	a_1	b_1	b_2	b_3	R^2	STANDARD ERROR OF ESTIMATE
TSS	29	802.5	1.761	-1.580	-0.904	0.76	37%
COD	26	1698.5	*	*	0.956	0.53	42%
TP	27	6.072	0.983	-0.990	-1.186	0.78	24%
ORTHO-P	26	1.838	0.357	*	-0.980	0.43	19%
TOTAL SOLUBLE-P	29	4.563	0.153	*	-1.072	0.80	18%
TOTAL-N	26	132.9	0.861	-0.766	-0.803	0.70	33%
TOTAL SOLUBLE-N	27	99.3	0.824	-0.704	-0.742	0.69	25%
AMMONIA	28	35.5	0.223	*	-0.727	0.63	64%
TKN	26	119.3	0.794	-0.719	-0.854	0.77	37%

---

*Independent variable is not included in regression model for this constituent

The standard error of the estimate is an assessment of the absolute amount of prediction accuracy. The standard error is computed as the standard deviation of the actual values from the values predicted by the models. Only models for which all variables are significant at the 0.05 significance level were included in the final regression models. Regression analyses were performed on log-transformed variables. The one-sided K-S test for normality was used to confirm that the wet pond efficiency datasets are lognormally distributed. The R^2 for most of the model regression models are fairly good. Ortho-P exhibits a rather low R^2 value; however, the standard error of the estimate, which gives an indication of the absolute amount of unexplained variation, is very low. Figure 4 is a scatterplot of observed versus predicted ortho-P removal efficiences (%). The observed values are plotted along the ordinate and the predicted values along the abscissa. Figure 4 shows that while the correlation between the predicted and observed ortho-P removal efficiencies is only fair, the absolute prediction accuracy of the model is quite good given the very high ortho-P removal rates noted for most events. Figures 4 through 12 are similar scatterplots for the constituents listed in Table 34. Based on the 29 events available at the wet ponds, cumulative inflow loads and cumulative predicted and observed outflow loads are presented in Table 35. The relative error of the predicted outflow loadings indicate that these models are fairly good in terms of long-term pollutant removal projections.

Volume Control Assessments

Introduction. Evaluation of infiltration pits pollutant removal efficiencies is more difficult than the detention basin performances discussed above. Only the outflow from infiltration pit BMP's was monitored. At the Burke Village Centre site, gravel infiltration trenches lined the edge of a suburban shopping center parking lot providing approximately 11,000 cu ft (0.67 in) of storage. There was no uncontrolled shopping center site monitoring data with which to compare runoff loading from Burke Village Centre. At the Dandridge site, which was located in a suburban townhouse development, three parallel subsoil gravel trenches provided approximately 3,300 cu ft of storage each (1.11 inch total). It should be noted that only 48% of the drainage area at this site is served by the infiltration BMP (e.g., the area draining to the infiltration pits). Over half of the drainage area should exhibit runoff characteristic of uncontrolled conditions. There were two NURP monitoring sites with which to compare Dandridge. These sites were the Stedwick Inflow Station and the Lakeridge Inflow station. These sites are inflow stations to dry pond BMP's and should be representative of uncontrolled conditions.

Infiltration Pit/Porous Pavement Analyses

- Burke Village Centre-Rockville City Center: Due to the lack of an uncontrolled NURP shopping center monitoring site, only qualitative assessments can be made regarding pollutant removal efficiencies at this site. Previous modeling studies (1) had projected the following removal rates for a volume control with similar storage capacity and which drained a commercial land use:

FIGURE 4

PREDICTED VS. OBSERVED BMP POLLUTANT REMOVAL EFFICIENCIES (PERCENT)
ORTHO PHOSPHORUS

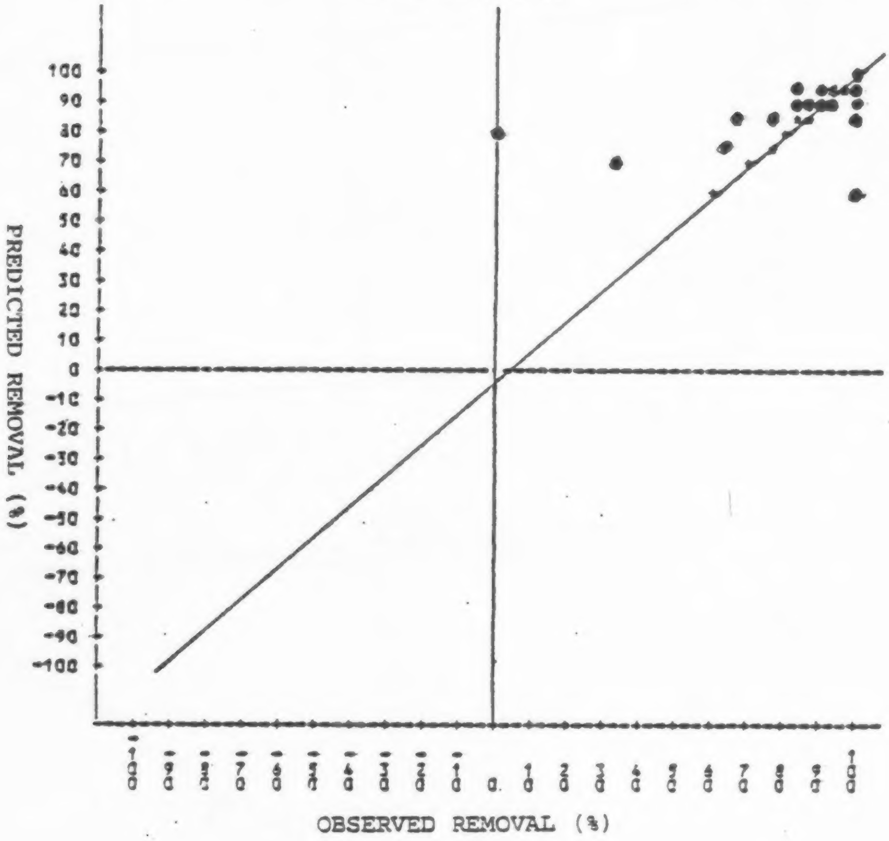


FIGURE 5

PREDICTED VS. OBSERVED BMP POLLUTANT REMOVAL EFFICIENCIES (PERCENT)
TOTAL SUSPENDED SOLIDS

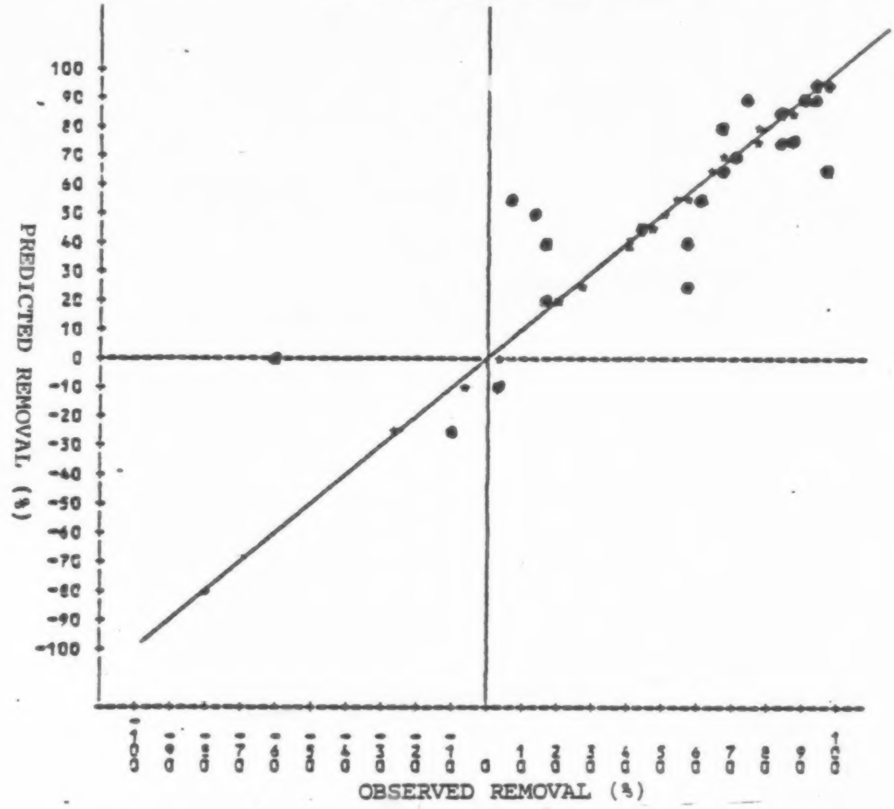
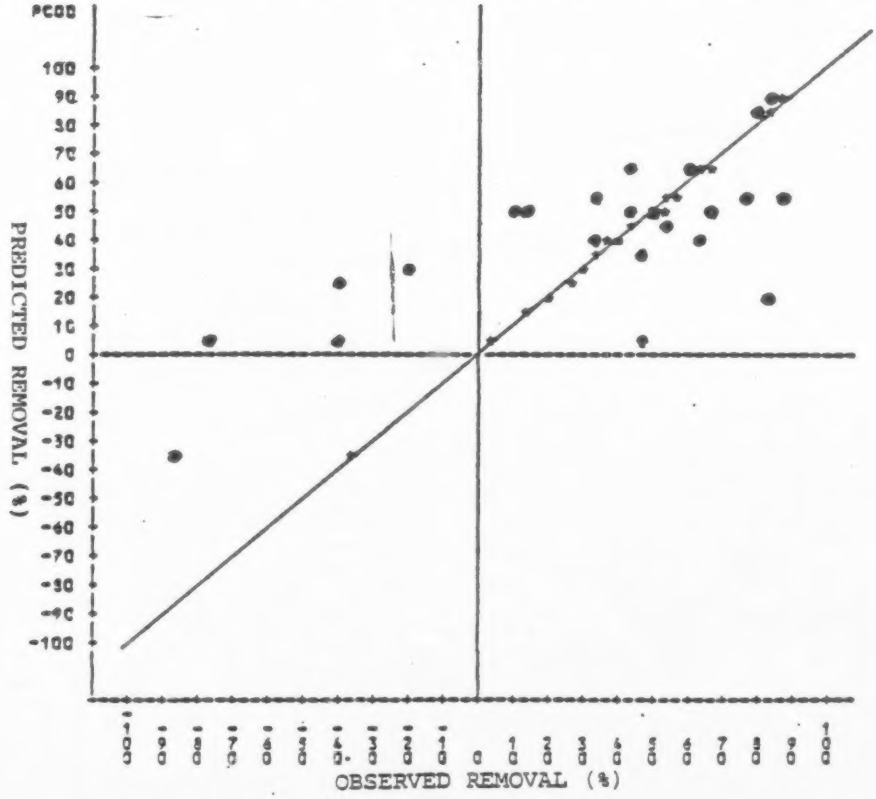


FIGURE 6

PREDICTED VS. OBSERVED BMP POLLUTANT REMOVAL EFFICIENCIES (PERCENT)
CHEMICAL OXYGEN DEMAND



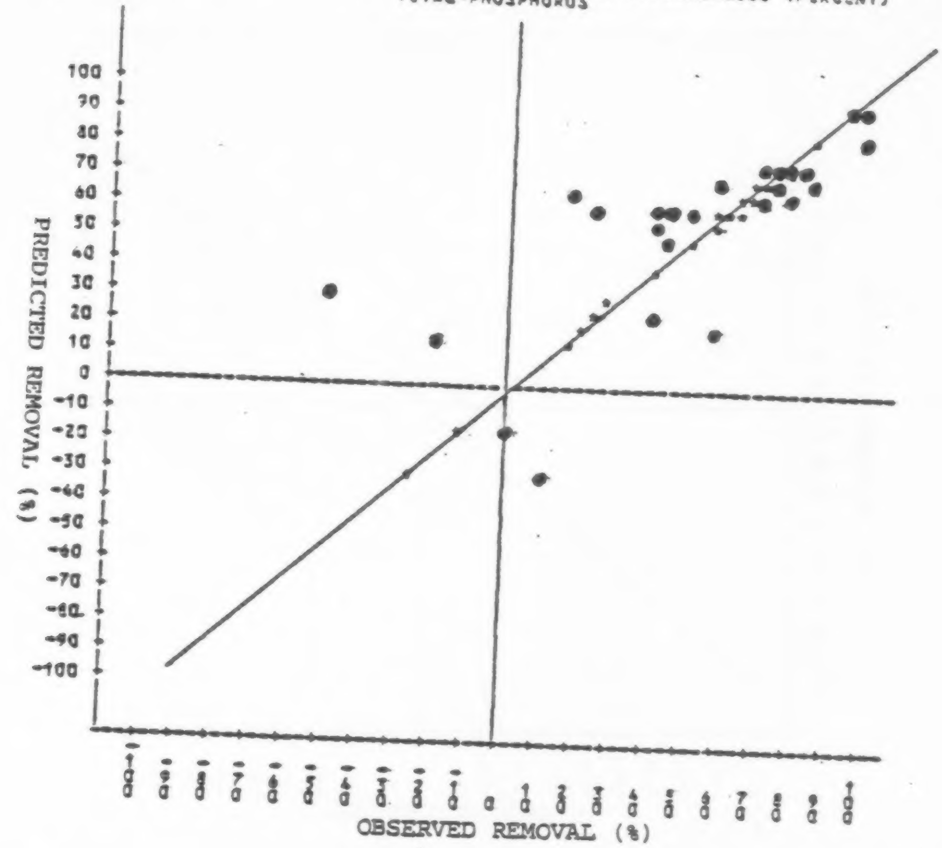


FIGURE 7

PREDICTED VS. OBSERVED BMP POLLUTANT REMOVAL EFFICIENCIES (PERCENT)
TOTAL-PHOSPHORUS

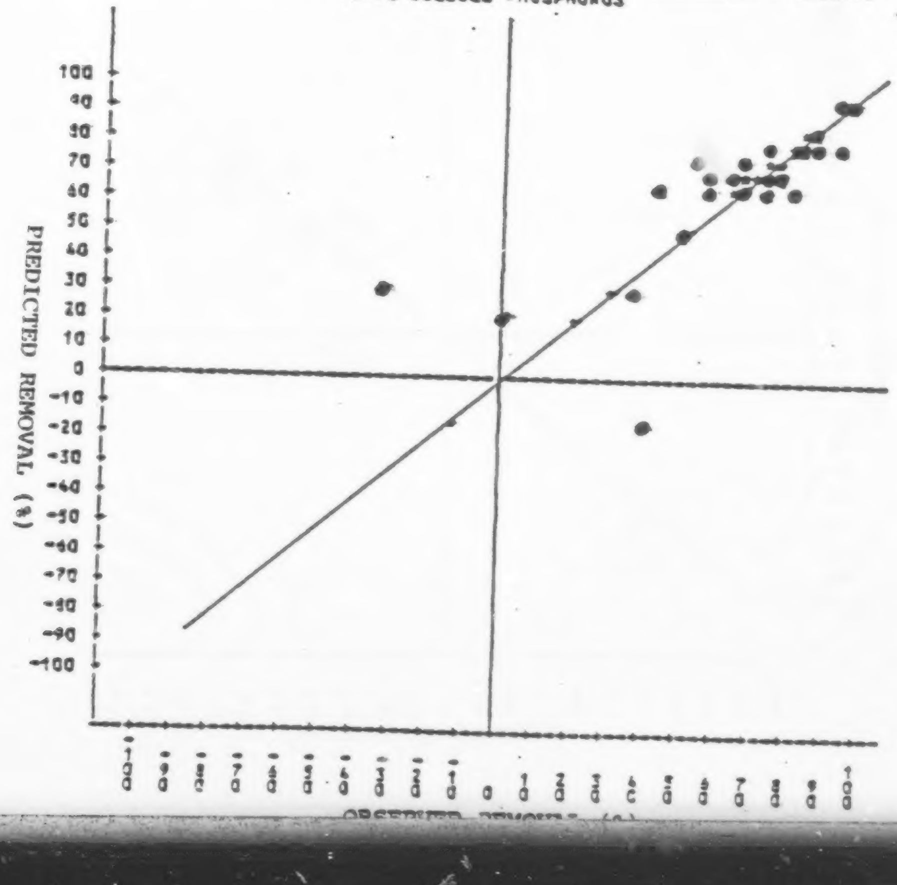


FIGURE 8

PREDICTED VS. OBSERVED BMP POLLUTANT REMOVAL EFFICIENCIES (PERCENT)
TOTAL SOLUBLE PHOSPHORUS

FIGURE 9

PREDICTED VS. OBSERVED BMP POLLUTANT REMOVAL EFFICIENCIES (PERCENT)
TOTAL NITROGEN

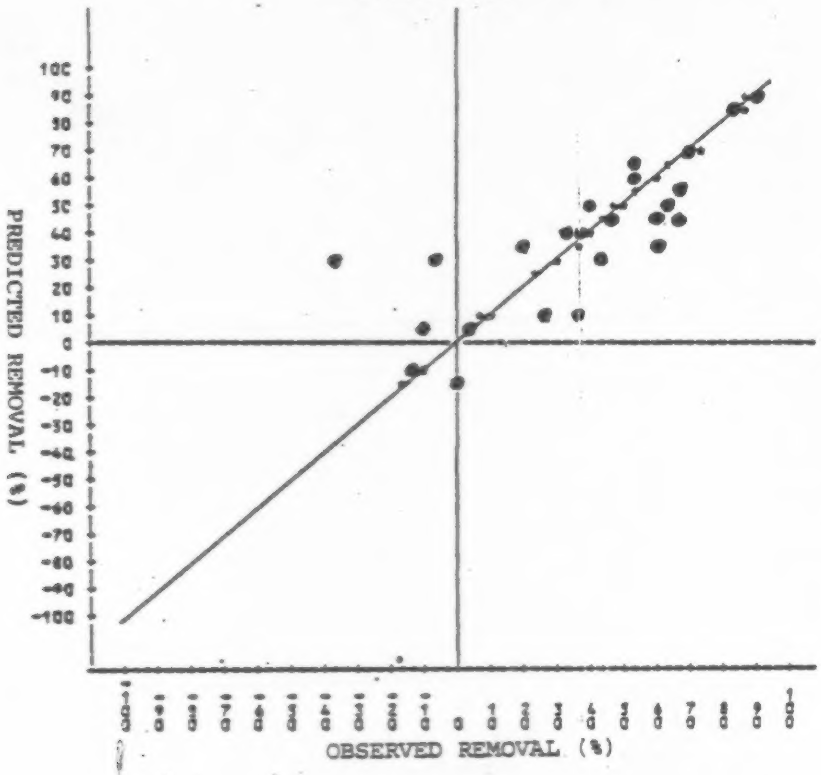


FIGURE 10

PREDICTED VS. OBSERVED BMP POLLUTANT REMOVAL EFFICIENCIES (PERCENT)
TOTAL SOLUBLE NITROGEN

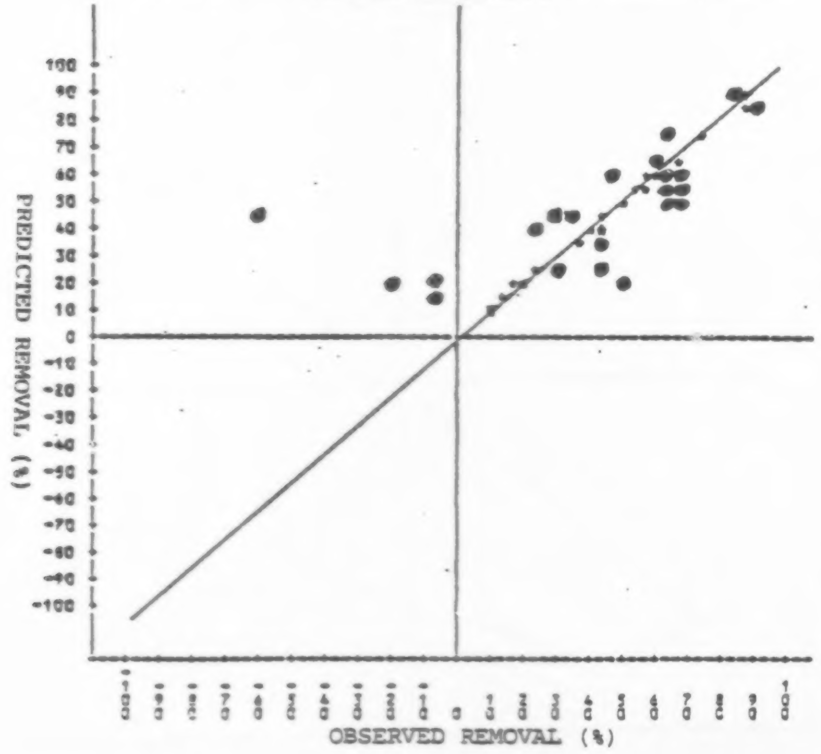


FIGURE 11

PREDICTED VS. OBSERVED BMP POLLUTANT REMOVAL EFFICIENCIES (PERCENT)
AMMONIA-N

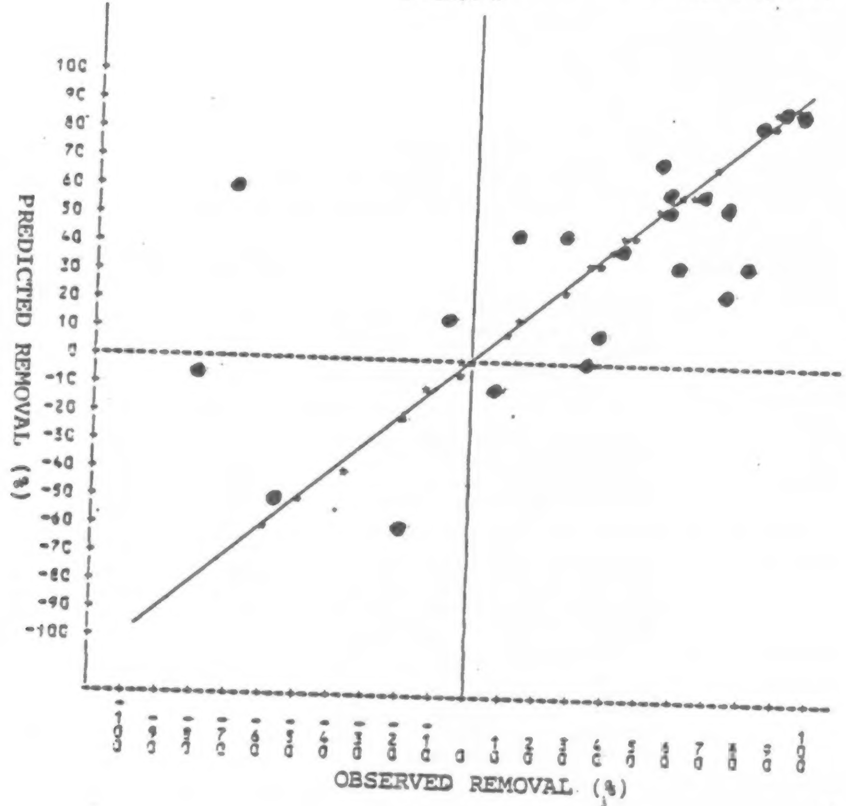


FIGURE 12

PREDICTED VS. OBSERVED BMP POLLUTANT REMOVAL EFFICIENCIES (PERCENT)
TOTAL KJELDAHL NITROGEN

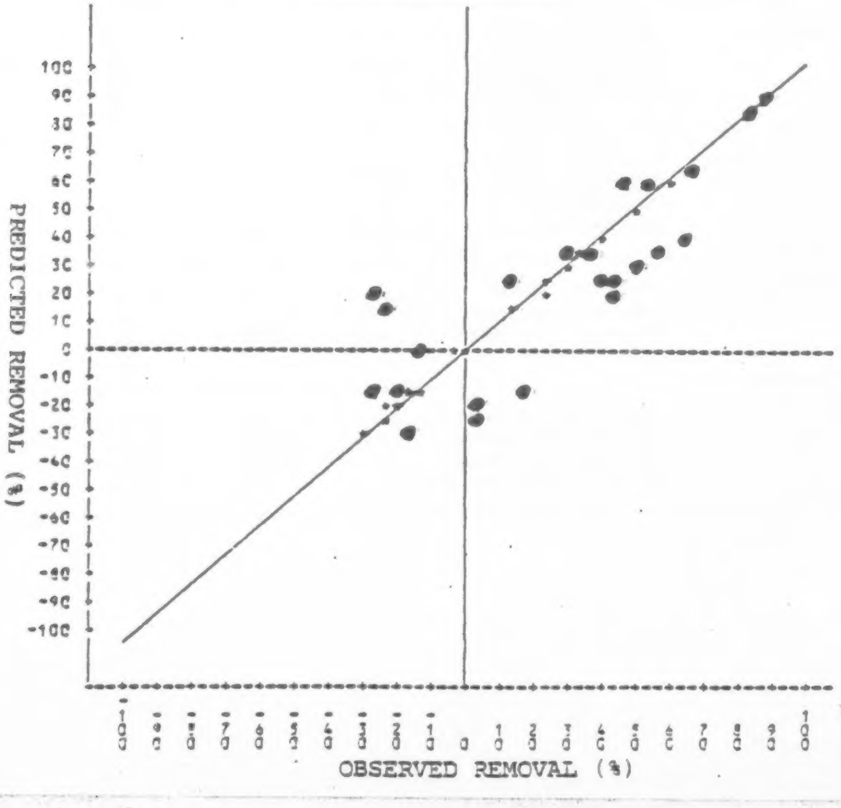


TABLE 35

WET PONDS: CUMULATIVE INFLOW LOADS, OBSERVED AND PREDICTED LOAD REMOVAL

CONSTITUENT		BURKE (WET POND)	WESTLEIGH (WET POND)	POOLED WET PONDS
TSS	CUMULATIVE INFLOW LOAD (lbs/ac)	13.0	14.3	27.3
	OBSERVED LOAD REMOVED (lbs/ac)	3.5	11.2	14.7
	PREDICTED LOAD REMOVED (lbs/ac)	2.8	10.3	13.1
	RELATIVE ERROR LOAD REMOVAL (%)	-20%	-8%	-11%
COD	CUMULATIVE INFLOW LOAD (lbs/ac)	24.7	12.8	37.5
	OBSERVED LOAD REMOVED (lbs/ac)	4.4	5.6	10.0
	PREDICTED LOAD REMOVED (lbs/ac)	7.8	6.5	14.3
	RELATIVE ERROR LOAD REMOVAL (%)	77%	11%	40%
TOTAL-P	CUMULATIVE INFLOW LOAD (lbs/ac)	0.21	0.08	0.29
	OBSERVED LOAD REMOVED (lbs/ac)	0.14	0.05	0.19
	PREDICTED LOAD REMOVED (lbs/ac)	0.13	0.05	0.18
	RELATIVE ERROR LOAD REMOVAL (%)	-7%	0%	-5%
ORTHO-P	CUMULATIVE INFLOW LOAD (lbs/ac)	0.093	0.039	0.132
	OBSERVED LOAD REMOVED (lbs/ac)	0.075	0.035	0.110
	PREDICTED LOAD REMOVED (lbs/ac)	0.082	0.036	0.118
	RELATIVE ERROR LOAD REMOVAL (%)	9%	3%	7%
TOTAL SOLUBLE-P	CUMULATIVE INFLOW LOAD (lbs/ac)	0.18	0.05	0.23
	OBSERVED LOAD REMOVED (lbs/ac)	0.14	0.04	0.18
	PREDICTED LOAD REMOVED (lbs/ac)	0.14	0.04	0.18
	RELATIVE ERROR LOAD REMOVED (%)	0%	0%	0%
TOTAL-N	CUMULATIVE INFLOW LOAD (lbs/ac)	1.54	0.62	2.16
	OBSERVED LOAD REMOVED (lbs/ac)	0.45	0.15	0.60
	PREDICTED LOAD REMOVED (lbs/ac)	0.26	0.15	0.41
	RELATIVE ERROR LOAD REMOVAL (%)	-42%	0%	-36%
TOTAL SOLUBLE N	CUMULATIVE INFLOW LOAD (lbs/ac)	1.33	0.45	1.78
	OBSERVED LOAD REMOVED (lbs/ac)	0.40	0.19	0.59
	PREDICTED LOAD REMOVED (lbs/ac)	0.37	0.16	0.53
	RELATIVE ERROR LOAD REMOVAL (%)	-8%	-22%	-10%
AMMONIA-N	CUMULATIVE INFLOW LOAD (lbs/ac)	0.171	0.119	0.290
	OBSERVED LOAD REMOVED (lbs/ac)	0.007	0.055	0.062
	PREDICTED LOAD REMOVED (lbs/ac)	0.005	0.061	0.066
	RELATIVE ERROR LOAD REMOVAL (%)	-29%	11%	6%
TKN	CUMULATIVE INFLOW LOAD (lbs/ac)	1.09	0.445	1.54
	OBSERVED LOAD REMOVED (lbs/ac)	0.148	0.079	0.23
	PREDICTED LOAD REMOVED (lbs/ac)	0.031	0.050	0.08
	RELATIVE ERROR LOAD REMOVAL (%)	-79%	-43%	-67%

Annual Sediment Removal:	88%-99%
Annual Total-P Removal:	58%-69%
Annual Total-N Removal:	36%-42%
Annual BOD Removal:	78%-89%
Annual Lead Removal:	82%-94%
Annual Zinc Removal:	82%-94%

Comparisons with the 208 shopping center sites suggest that there may be significant removal taking place at the NURP shopping center land use category. The NURP sites within this category are Burke Centre and Rockville City Center (porous pavement), thus both are representative of BMP control practice. Comparisons with the 208 sediment loading data should be regarded cautiously because of possible misrepresentation of sediment loading by the sequential discrete sampling technique used during the 208 study. Total-P and total-N loadings were found to be quite similar for NURP and 208 categories where there were uncontrolled NURP monitoring sites for comparison. Therefore, a comparison of NURP and 208 loading rates for the shopping center category may give some insight regarding pollutant removals which might be expected at volume control BMP's. The ratio of the NURP to 208 median loading rates expressed as a percent removal follows:

Sediment:	88%
Total-P:	55%
Total-N:	-7%
COD:	72%
EPb:	50%
EZn:	75%

While these comparisons are not intended to quantify BMP efficiencies, they do suggest that significant pollutant removal is occurring at the volume control BMP's. Nitrogen is the only constituent which does not fairly well bracket projected removal efficiencies.

The porous pavement BMP at the Rockville City Center seems to have resulted in significant benefits in terms of stormwater management. The mean peak runoff rate measured during the 35 monitored events was 0.22 cfs. Precipitation totals for three of these events were greater than 1.0 inch including one event of approximately two inches. The average duration of a monitored runoff event was 28.5 hours. The porous pavement with a high void aggregate base is very effective for detaining stormwater and reducing peak runoff rates.

- Dandridge: Loading data from Dandridge was compared to data from Lakeridge and Stedwick inflow stations. Tables 36 and 37 summarize median, means, and the coefficients of variation for the individual sites and the 'no control' sites pooled (e.g., Lakeridge +

TABLE 36

COMPARISON OF VOLUME CONTROL VS. NO CONTROL RUNOFF STATISTICS[1]
LOGNORMAL DISTRIBUTION ASSUMED
UNIT AREA LOADS

CONSTITUENT	STATISTIC	DANDRIDGE (INFIL. PITS)	LAKERIDGE (DRY POND INFLOW)	STEDWICK (DRY POND INFLOW)	POOLED* NO CONTROL
RUNOFF (inches)	MEDIAN	0.23	0.20	0.19	0.20
	MEAN	0.30	0.30	0.25	0.27
	COEFFICIENT OF VARIATION	0.90	1.13	0.80	0.92
	N	46	18	26	44
TSS (lbs/ac)	MEDIAN	0.84	4.73	1.45	2.35
	MEAN	1.52	23.90	2.61	7.46
	COEFFICIENT OF VARIATION	1.51	4.95	1.49	3.01
	N	44	18	26	44
TOTAL P (lbs/ac)	MEDIAN	0.02	0.01	0.01	0.01
	MEAN	0.04	0.03	0.02	0.02
	COEFFICIENT OF VARIATION	1.31	1.90	0.89	1.26
	N	45	18	26	44
ORTHO-P (lbs/ac)	MEDIAN	0.01	0.0	0.01	0.0
	MEAN	0.03	0.01	0.01	0.01
	COEFFICIENT OF VARIATION	2.00	3.05	0.94	2.06
	N	42	18	24	42
TOTAL N (lbs/ac)	MEDIAN	0.13	0.09	0.11	0.10
	MEAN	0.19	0.15	0.14	0.14
	COEFFICIENT OF VARIATION	1.06	1.36	0.76	1.00
	N	46	18	25	43
NITRATE-N (lbs/ac)	MEDIAN	0.04	0.02	0.03	0.03
	MEAN	0.06	0.05	0.04	0.04
	COEFFICIENT OF VARIATION	1.14	1.66	0.78	1.12
	N	46	18	26	44

[1] RUNOFF INTERVAL > 0.06

*LAKERIDGE + STEDWICK

TABLE 37

COMPARISON OF VOLUME CONTROL VS. NO CONTROL RUNOFF STATISTICS[1]
LOGNORMAL DISTRIBUTION ASSUMED
UNIT AREA LOADS

CONSTITUENT	STATISTIC	DANDRIDGE (INFIL. PITS)	LAKERIDGE (DRY POND INFLOW)	STEDWICK (DRY POND INFLOW)	POOLED* NO CONTROL
AMMONIA-N (lbs/ac)	MEDIAN	0.02	0.01	0.01	0.01
	MEAN	0.04	0.03	0.02	0.02
	COEFFICIENT OF VARIATION	1.43	2.76	1.00	1.65
	N	46	18	26	44
TKN (lbs/ac)	MEDIAN	0.09	0.06	0.08	0.07
	MEAN	0.13	0.11	0.10	0.10
	COEFFICIENT OF VARIATION	1.12	1.45	0.81	1.06
	N	46	18	25	43
COD (lbs/ac)	MEDIAN	2.05	2.21	1.67	1.86
	MEAN	2.86	4.62	2.15	2.90
	COEFFICIENT OF VARIATION	0.98	1.84	0.82	1.20
	N	45	17	26	43
EPB (lbs/ac)	MEDIAN	0.006	0.006	0.005	0.005
	MEAN	0.007	0.007	0.005	0.006
	COEFFICIENT OF VARIATION	0.78	0.49	0.43	0.47
	N	3	5	5	10
EZN (lbs/ac)	MEDIAN	0.003	0.004	0.003	0.003
	MEAN	0.006	0.006	0.004	0.005
	COEFFICIENT OF VARIATION	1.25	1.19	1.06	1.11
	N	39	18	25	43
ECU (lbs/ac)	MEDIAN	0.001	0.004	0.001	0.002
	MEAN	0.002	0.009	0.001	0.006
	COEFFICIENT OF VARIATION	1.19	2.18	0.59	2.74
	N	12	3	2	5

[1] RUNOFF INTERVAL > 0.06

*LAKERIDGE + STEDWICK

Stedwick). Higher runoff volumes were recorded at Dandridge;* therefore, a runoff threshold was applied to all three datasets to drop out the minor events which could bias comparisons. Inspection of the medians presented in Tables 36 and 37 shows that only sediment exhibits lower median loading rates at the volume control site. In many cases, the 'no control' sites exhibit lower median loading rates. To statistically check these findings, a series of parametric and nonparametric statistical tests was performed on the 'volume control' (e.g., Dandridge) datasets and the 'no control' (e.g., Lakeridge + Stedwick) datasets. The tests are analogous to the statistics presented in an earlier section relating the NURP study to the 208 study monitoring data. For descriptions of these tests and their applications, the reader is referred to section III of this report. The purpose of the statistical analyses of the 'volume control' and 'no control' datasets is to determine whether there is a statistically significant difference between the datasets in terms of distribution or central value (e.g., mean or median). Results are presented in Table 38. As described above, a runoff threshold was applied to both datasets to ensure that there were no significant differences in volumes between the two datasets. Table 38 shows that sediment is the only pollutant for which significantly lower loading rates were monitored at the volume control site. For total-P, ortho-P, nitrate-N, and ammonia-N, the 'no control' sites exhibit lower loading rates. In general, the suspended loadings are lower at the volume control site while the dissolved loadings are lower at the 'no control' sites. The 'no control' sites include Lakeridge which was monitored using a sequential discrete sampling technique. Since the results presented in this report have raised questions about the adequacy of this technique to describe suspended and dissolved loadings, it is felt that these results are inconclusive. The difficulty of these comparisons was also exacerbated by the following factors characterizing the 'volume control' site: (1) much higher percent percent imperviousness, (2) higher runoff volumes, and (3) only 48% BMP coverage.

Grass Swale Assessments

Introduction. Three of the NURP monitoring sites drained large lot or medium density single family subdivisions which were served by roadside grass swales instead of curb and gutter systems. Some of the purposes of grass swales are: (1) to utilize the natural capacity of grassed surfaces to reduce runoff volumes, and associated pollutant loadings (15), (2) to remove coarse solids through sedimentation and filtration as a result of reduced runoff velocities, and (3) to increase opportunities for infiltration of impervious area runoff within the grass swales (1). Evaluations of grass swales were based upon a method similar to the one

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*Percent impervious cover is approximately 20% higher at Dandridge in comparison to Lakeridge and Stedwick.

TABLE 30

COMPARISON OF VOLUME CONTROL SITES vs. NO CONTROL SITES RUNOFF STATISTICS[1] DANDRIDGE (INFILTRATION PITS) vs. LAKERIDGE AND STEDWICK (DRY POND INFLOW)[1]
LAND USE; TOWNHOUSE/GARDEN APARTMENT
UNIT AREA LOADS

CONSTITUENT	N VOLUME CONTROL	N NO CONTROL	PARAMETRIC STATISTICS[2] LEVEL OF SIGNIFICANCE: ONE-SIDED K-S TEST VOLUME CONTROL	ONE-SIDED K-S TEST NO CONTROL	T-STATISTIC ON MEANS	F-STATISTIC ON VARIANCES	NONPARAMETRIC STATISTICS LEVEL OF SIGNIFICANCE: TWO-SIDED K-S DISTRIBUTION TEST	WILCOXON RANK SUM MEDIAN TEST	HYPOTHESIS: SIGNIFICANTLY DIFFERENT DISTRIBUTION	SIGNIFICANTLY DIFFERENT MEAN OR MEDIAN	HIGHER MEAN/MEDIAN VALUE
RUNOFF (inches)	46	44	>0.20	*	0.41	0.94	0.13	0.30	NO	NO	---
TSS (lbs/ac)	44	44	>0.20	0.15	*	*	*	*	NO	YES	NO CONTROL
COD (lbs/ac)	45	43	>0.20	>0.20	0.61	0.35	0.73	0.52	NO	NO	---
TOTAL-P (lbs/ac)	45	44	>0.20	>0.20	*	0.06	0.16	*	NO	YES	VOLUME CONTROL
ORTHO-P (lbs/ac)	42	42	>0.20	>0.20	*	0.93	*	*	NO	YES	VOLUME CONTROL
TOTAL-N (lbs/ac)	46	43	>0.20	>0.20	0.14	0.77	0.18	0.10	NO	NO	---
NITRATE-N (lbs/ac)	46	44	0.15	0.20	*	0.94	0.06	*	NO	YES	VOLUME CONTROL
AMMONIA-N	46	44	0.15	>0.20	*	0.58	*	*	NO	YES	VOLUME CONTROL
TKN (lbs/ac)	46	43	>0.20	>0.20	0.31	0.82	0.51	0.26	NO	NO	---
EPB (lbs/ac)	3	10	--	>0.20	0.80	0.29	0.59	0.19	NO	NO	---
PBF (lbs/ac)	5	8	--	--	--	--	--	--	--	--	---
EZN (lbs/ac)	39	43	>0.20	0.05	0.66	0.60	0.47	0.85	NO	NO	---
ECU (lbs/ac)	12	5	>0.20	>0.20	0.77	0.22	0.53	0.17	NO	NO	---

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[1] Runoff Threshold > 0.06"
[2] Assumed Lognormal Distribution
*Level of Significance is less than 0.05

presented for volume controls. Runoff monitoring data from sites served by grass swales was compared to monitoring data from sites representing similar land uses which were drained by curb and gutter systems. This method was found to be less than satisfactory in terms of quantifying the pollutant removal efficiencies of grass swales. Previous modeling studies (1) projected removal efficiencies of 10%-20% for heavy metals and 7%-12% for the plant nutrients and BOD. Unfortunately, these efficiencies are well within the range of variation one might expect between uncontrolled sites of a given land use. Errors as great as plus or minus 15%-20% also typically characterize monitoring and laboratory analyses. If two different watersheds are to be compared (e.g., one with grass swales and one with curb and gutters), great care must be taken in site selection to ensure that land use, soils, slope, traffic volume and other watershed characteristics are identical. Close proximity of the watersheds is also important to ensure that local meteorologic conditions are not biasing the comparisons. Unfortunately, due to budget constraints, the curb and gutter sites monitored in large lot and medium density land use classifications had to serve dual purposes: first as inflow stations to detention basin BMP's, and secondarily as curb and gutter sites for comparison with grass swale sites. Given the low pollutant removals projected for these BMP's, assessments of removal efficiencies cannot accommodate the compromises in site selection which were necessary under this monitoring study.

Site visits performed by NVPDC staff during storm events also raised questions about velocities and contact times of runoff within the grass swale at the three NURP monitoring sites. Grass swales can only handle a limited amount of runoff volume and velocity before the runoff must be diverted into a storm sewer or other impervious channel system. Detailed analyses were undertaken to determine the average length and slopes which characterize the swales at each montitoring site. The average slopes and swale lengths presented in Table 2 are based on ten to fifteen measurements at each site. SCS tables (16) were used to approximate flow velocities at the swale sites. Given an average swale length and an average flow velocity, rough estimates could be made for the travel times of runoff within the swale. This provides an indication of the typical length of time that runoff is in contact with grassed areas (e.g., contact time). At all sites, contact times were calculated to be 5 minutes or less. A review of the literature on overland treatment of wastewater indicates contact times on the order of one hour are required for effective pollutant removal (17,18,19).

An extensive study (21) of core samples at the NURP grass swale sites concluded that there was no accumulation of heavy metals in the residential swale drain soils from overland flow of urban stormwater runoff. Zinc was the only exception to these findings; however, accumulations of zinc were traced back to the use of galvanized culverts used under driveways at the swale sites. The solubility of zinc was apparently increased due to acid precipitation.

Tables 39 and 40 summarize the medians, means, and coefficients of variation of the grass swale/curb and gutter site comparisons. Only synoptic events (e.g., those events simultaneously measured at both sites) are included in these tables. Stratton Woods is compared to Westleigh Inflow. Dufief is also compared to Westleigh Inflow, however, the synoptic events used for this comparison are not the same as are used with Stratton Woods. Fairidge is compared to Burke Pond Inflow.

Stratton Woods. For the eighteen synoptic events monitored at both Stratton Woods and Westleigh, Table 39 shows that runoff volumes were significantly higher at Stratton Woods, the grass swale site. This is probably due to the different soils found at the two sites. Approximately 70% of the soils at Stratton Woods are hydrologic soil types C or D while 85% of the drainage area at Westleigh is hydrologic soil type B. The lower infiltration capacities of soil types C and D could explain the higher runoff volumes noted at Stratton Woods. Table 41 summarizes the series of parametric and nonparametric statistitcal tests which were performed on the Stratton Woods (i.e., grass swale) and Westleigh (i.e., curb and gutter) datasets. The purpose of these tests is to determine whether there is a statistically significant difference between the 'grass swale' loading datasets and the 'curb and gutter' loading datasets in terms of frequency distribution or central values (e.g., mean or median). The columns labeled 'HYPOTHESIS' indicate whether there are significant differences at the 0.05 probability cutoff for the 95% confidence interval in terms of distribution or central value. The final column indicates which dataset has the higher mean or median value. Table 41 shows that for synoptic events, Stratton Woods exhibits significantly higher runoff volumes. The higher volumes bias the loading comparisons which show the grass swale loadings to be higher for total-P and total-N as well as many of the dissolved fractions. Table 41 should not be interpreted as demonstrating that higher loadings are coming from the grass swale site, rather, these findings exemplify the pitfalls of comparing loading datasets without first ensuring that there are no significant differences in runoff volumes. By iteratively applying a runoff threshold to both datasets and performing the statistical tests, a runoff interval was found within which there was no significant difference between the runoff volumes measured at Stratton Woods and Westleigh. Summary statistics were generated for the loading datasets from events which fell within this runoff interval. These results are presented in Table 42. No significant difference could be found for the majority of the constituents. Higher zinc loadings were found at Stratton Woods. This may be related to higher traffic volumes; however, no data was available to confirm this.

Dufief. Analyses similar to the ones described above were performed on the Dufief loading datasets. Only eight storm events were monitored at this grass swale site. Table 43 summarizes the statistical comparisons of the synoptic loading datasets at Dufief and Westleigh Inflow. No significant differences were found in runoff or pollutant loadings for any constituent. Similar tests were performed on the complete datasets for both sites (e.g., non-synoptic events were included). These results are presented in Table 44. Again no significant differences were found for all constituents except

TABLE 39

COMPARISON OF GRASS SWALE VS. CURB & GUTTER RUNOFF STATISTICS SYNOPTIC EVENTS ONLY ASSUMED LOGNORMAL DISTRIBUTION

CONSTITUENT	STATISTIC	STRATTON WOODS (GRASS SWALE)	WESTLEIGH INFLOW (CURB & GUTTER)	DUPIEF (GRASS SWALE)	WESTLEIGH INFLOW (CURB & GUTTER)	FAIRIDGE (GRASS SWALE)	BURKE POND INFLOW (CURB & GUTTER)
RUNOFF (inches)	MEDIAN	0.15	0.07	0.03	0.08	0.12	0.11
	MEAN	0.21	0.13	0.04	0.21	0.22	0.22
	COEFFICIENT OF VARIATION	1.08	1.73	0.94	2.46	1.52	1.72
	N	18	18	7	7	28	28
TSS (lbs/ac)	MEDIAN	1.22	0.66	0.30	0.67	0.36	0.29
	MEAN	3.11	3.99	0.60	9.07	0.69	0.97
	COEFFICIENT OF VARIATION	2.35	5.96	1.73	13.54	2.51	2.16
	N	18	18	7	7	25	27
TOTAL-P (lbs/ac)	MEDIAN	0.01	0.0	0.0	0.0	0.0	0.01
	MEAN	0.02	0.01	0.01	0.02	0.01	0.02
	COEFFICIENT OF VARIATION	1.36	2.59	1.07	3.30	2.01	2.08
	N	16	18	4	7	27	26
ORTHO-P (lbs/ac)	MEDIAN	0.01	0.0	0.0	0.0	0.0	0.0
	MEAN	0.01	0.0	0.0	0.01	0.01	0.01
	COEFFICIENT OF VARIATION	1.37	3.19	1.14	3.17	2.38	3.03
	N	18	15	6	7	26	25
TOTAL-N (lbs/ac)	MEDIAN	0.08	0.03	0.02	0.04	0.08	0.06
	MEAN	0.13	0.06	0.02	0.10	0.19	0.11
	COEFFICIENT OF VARIATION	1.25	1.91	1.19	2.55	2.24	1.51
	N	16	18	5	7	25	26
NITRATE-N (lbs/ac)	MEDIAN	0.01	0.01	0.0	0.01	0.02	0.02
	MEAN	0.02	0.02	0.0	0.03	0.04	0.04
	COEFFICIENT OF VARIATION	1.21	2.02	1.09	2.88	1.82	2.05
	N	18	18	7	7	26	28

TABLE 40

COMPARISON OF GRASS SWALE VS. CURB & GUTTER RUNOFF STATISTICS SYNOPTIC EVENTS ONLY ASSUMED LOGNORMAL DISTRIBUTION

CONSTITUENT	STATISTIC	STRATTON WOODS (GRASS SWALE)	WESTLEIGH INFLOW (CURB & GUTTER)	DUFIEF (GRASS SWALE)	WESTLEIGH INFLOW (CURB & GUTTER)	FAIRIDGE (GRASS SWALE)	BURKE POND INFLOW (CURB & GUTTER)
NH3 (lbs/ac)	MEDIAN	0.01	0.0	0.0	0.01	0.01	0.01
	MEAN	0.02	0.01	0.0	0.02	0.03	0.01
	COEFFICIENT OF VARIATION	1.21	2.79	1.43	2.67	2.26	2.08
	N	18	18	7	7	27	27
TKN (lbs/ac)	MEDIAN	0.07	0.02	0.01	0.03	0.05	0.4
	MEAN	0.11	0.05	0.02	0.07	0.14	0.07
	COEFFICIENT OF VARIATION	1.28	1.97	1.18	2.56	2.40	1.60
	N	16	18	5	7	27	26
COD (lbs/ac)	MEDIAN	1.73	0.64	0.57	0.73	1.31	0.79
	MEAN	2.60	1.34	0.61	2.18	2.70	1.47
	COEFFICIENT OF VARIATION	1.19	1.83	0.38	2.80	1.80	1.57
	N	17	18	6	7	26	28
EPB (lbs/ac)	MEDIAN	--	0.004	--	--	--	--
	MEAN	--	0.006	--	--	--	--
	COEFFICIENT OF VARIATION	--	0.89	--	--	--	--
	N	0	3	0	1	0	0
EZN (lbs/ac)	MEDIAN	0.003	0.001	0.0011	0.0011	0.0021	0.0008
	MEAN	0.005	0.002	0.0014	0.0014	0.005	0.001
	COEFFICIENT OF VARIATION	1.46	2.01	0.87	0.84	2.16	1.14
	N	15	12	7	5	27	16
ECU (lbs/ac)	MEDIAN	0.0006	0.0003	--	--	0.44	0.82
	MEAN	0.0011	0.0009	--	--	0.92	1.05
	COEFFICIENT OF VARIATION	--	--	--	--	1.83	0.73
	N	7	2	1	2	6	6

TABLE 41

COMPARISON OF GRASS SWALE vs. CURB & GUTTER RUNOFF STATISTICS: STRATTON WOODS vs. WESTLEIGH INFLOW
SYNOPTIC EVENTS ONLY
LARGE LOT SINGLE FAMILY
UNIT AREA LOADS

CONSTITUENT	N GRASS SWALE	N CURB & GUTTER	PARAMETRIC STATISTICS[1] LEVEL OF SIGNIFICANCE				NONPARAMETRIC STATISTICS LEVEL OF SIGNIFICANCE		HYPOTHESIS		
			ONE-SIDED K-S TEST GRASS SWALE	ONE-SIDED K-S TEST CURB & GUTTER	T-STATISTIC ON MEANS	F-STATISTIC ON VARIANCES	TWO-SIDED K-S DISTRIBUTION TEST	WILCOXON RANK SUM MEDIAN TEST	SIGNIFICANTLY DIFFERENT DISTRIBUTION	SIGNIFICANTLY DIFFERENT MEAN OR MEDIAN	HIGHER MEAN/MEDIAN VALUE
RUNOFF (inches)	18	18	>0.20	>0.20	*	0.24	>0.13	*	NO	YES	GRASS SWALE
TSS (lbs/ac)	18	18	0.15	>0.20	0.27	0.19	>0.13	0.29	NO	NO	---
COD (lbs/ac)	17	18	>0.20	>0.20	*	0.31	0.06	*	NO	YES	GRASS SWALE
TOTAL-P (lbs/ac)	16	18	0.15	>0.20	*	0.20	0.08	*	NO	YES	GRASS SWALE
ORTHO-P (lbs/ac)	18	15	>0.20	>0.20	*	0.11	*	*	NO	YES	GRASS SWALE
TOTAL-N (lbs/ac)	16	18	>0.20	>0.20	*	0.34	0.09	*	NO	YES	GRASS SWALE
NITRATE-N (lbs/ac)	18	18	>0.20	>0.20	0.16	0.24	>0.13	0.30	NO	NO	---
AMMONIA-N (lbs/ac)	18	18	>0.20	>0.20	0.06	0.08	0.13	0.12	NO	NO	---
TKN (lbs/ac)	16	18	>0.20	>0.20	*	0.34	*	*	NO	YES	GRASS SWALE
EPB (lbs/ac)	0	3	--	--	--	--	--	--	--	--	---
PBF (lbs/ac)	--	--	--	--	--	--	--	--	--	--	---
EZN (lbs/ac)	15	12	>0.20	>0.20	*	0.53	*	*	NO	YES	GRASS SWALE
ECU (lbs/ac)	7	2	0.05	--	0.41	0.42	>0.10	0.12	NO	NO	---

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[1] Lognormal Distribution Assumed
*Level of Significance is less than 0.05

TABLE 42

COMPARISON OF GRASS SWALE vs. CURB & GUTTER RUNOFF STATISTICS: STRATTON WOODS vs. WESTLEIGH[1]
LAND USE: LARGE LOT SINGLE FAMILY
UNIT AREA LOADS

			PARAMETRIC STATISTICS[2] LEVEL OF SIGNIFICANCE				NONPARAMETRIC STATISTICS LEVEL OF SIGNIFICANCE		HYPOTHESIS		
			ONE-SIDED K-S TEST								
CONSTITUENT	N GRASS SWALE	N CURB & GUTTER	GRASS SWALE	CURB & GUTTER	T-STATISTIC ON MEANS	F-STATISTIC ON VARIANCES	TWO-SIDED K-S DISTRIBUTION TEST	WILCOXON RANK SUM MEDIAN TEST	SIGNIFICANTLY DIFFERENT DISTRIBUTION	SIGNIFICANTLY DIFFERENT MEAN OR MEDIAN	HIGHER MEAN/MEDIAN VALUE
RUNOFF (inches)	24	18	>0.20	0.10	0.75	0.09	0.10	0.08	NO	NO	---
TSS (lbs/ac)	24	18	>0.20	>0.20	0.79	0.52	0.20	0.75	NO	NO	---
COD (lbs/ac)	23	17	>0.20	0.20	0.20	0.48	*	0.06	NO	NO	---
TOTAL-P (lbs/ac)	21	18	0.05	>0.20	0.73	0.80	>0.20	0.46	NO	NO	---
ORTHO-P (lbs/ac)	24	14	0.15	>0.20	0.38	0.85	>0.10	0.26	NO	NO	---
TOTAL-N (lbs/ac)	21	18	>0.20	>0.20	0.39	0.50	>0.20	0.25	NO	NO	---
NITRATE-N (lbs/ac)	24	18	>0.20	>0.20	0.88	0.55	>0.20	0.64	NO	NO	---
AMMONIA-N (lbs/ac)	24	18	0.05	>0.20	0.85	0.28	>0.20	0.83	NO	NO	---
TKN (lbs/ac)	21	18	>0.20	0.15	0.21	0.48	>0.20	0.13	NO	NO	---
EPB (lbs/ac)	0	2	--	--	--	--	--	--	--	--	---
PBF (lbs/ac)	--	--	--	--	--	--	--	--	--	--	---
EZN (lbs/ac)	20	14	>0.20	0.15	*	0.49	*	*	NO	YES	GRASS SWALE
ECU (lbs/ac)	4	3	0.05	--	0.58	0.68	>0.20	0.96	NO	NO	---

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[1] Runoff Interval 0.05" < Runoff < 0.6"

[2] Lognormal Distribution Assumed

*Level of Significance is less than 0.05

TABLE 43

COMPARISON OF GRASS SWALE vs. CURB & GUTTER RUNOFF STATISTICS: DUFIEF vs. WESTLEIGH INFLOW
SYNOPTIC EVENTS ONLY
LARGE LOT SINGLE FAMILY
UNIT AREA LOADS

			PARAMETRIC STATISTICS[1] LEVEL OF SIGNIFICANCE				NONPARAMETRIC STATISTICS LEVEL OF SIGNIFICANCE		HYPOTHESIS		
			ONE-SIDED K-S TEST								
CONSTITUENT	N GRASS SWALE	N CURB & GUTTER	GRASS SWALE	CURB & GUTTER	T-STATISTIC ON MEANS	F-STATISTIC ON VARIANCES	TWO-SIDED K-S DISTRIBUTION TEST	WILCOXON RANK SUM MEDIAN TEST	SIGNIFICANTLY DIFFERENT DISTRIBUTION	SIGNIFICANTLY DIFFERENT MEAN OR MEDIAN	HIGHER MEAN/MEDIAN VALUE
RUNOFF (inches)	7	7	>0.20	0.05	0.15	0.20	0.05	0.10	NO	NO	---
TSS (lbs/ac)	7	7	0.10	>0.20	0.43	0.13	>0.21	0.34	NO	NO	---
COD (lbs/ac)	6	7	>0.20	>0.20	0.69	*	>0.15	0.35	NO	NO	---
TOTAL-P (lbs/ac)	4	7	0.15	>0.20	0.80	0.36	>0.12	0.51	NO	NO	---
ORTHO-P (lbs/ac)	6	7	>0.20	>0.20	0.79	0.26	>0.15	0.52	NO	NO	---
TOTAL-N (lbs/ac)	5	7	>0.20	>0.20	0.25	0.44	>0.12	0.19	NO	NO	---
NITRATE-N (lbs/ac)	7	7	>0.20	>0.20	0.13	0.23	0.05	0.06	NO	NO	---
AMMONIA-N (lbs/ac)	7	7	>0.20	>0.20	0.10	0.46	0.21	0.10	NO	NO	---
TKN (lbs/ac)	5	7	0.20	>0.20	0.31	0.44	>0.12	0.33	NO	NO	---
EBP (lbs/ac)	0	1	--	--	--	--	--	--	--	--	---
PBP (lbs/ac)	--	--	--	--	--	--	--	--	--	--	---
EZN (lbs/ac)	7	5	>0.20	>0.20	0.99	1.0	>0.21	0.31	NO	NO	---
ECU (lbs/ac)	1	2	--	--	--	--	>0.21	--	--	--	---

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[1] Lognormal Distribution Assumed
*Level of Significance is less than 0.05

TABLE 44

COMPARISON OF GRASS SWALE vs. CURB & GUTTER RUNOFF STATISTICS; DUPIEF vs. WESTLEIGH POND INFLOW
LAND USE: LARGE LOT SINGLE FAMILY
UNIT AREA LOADS

			PARAMETRIC STATISTICS[1] LEVEL OF SIGNIFICANCE				NONPARAMETRIC STATISTICS LEVEL OF SIGNIFICANCE		HYPOTHESIS		
			ONE-SIDED K-S TEST								
CONSTITUENT	N GRASS SWALE	N CURB & GUTTER	GRASS SWALE	CURB & GUTTER	T-STATISTIC ON MEANS	F-STATISTIC ON VARIANCES	TWO-SIDED K-S DISTRIBUTION TEST	WILCOXON RANK SUM MEDIAN TEST	SIGNIFICANTLY DIFFERENT DISTRIBUTION	SIGNIFICANTLY DIFFERENT MEAN OR MEDIAN	HIGHER MEAN/MEDIAN VALUE
RUNOFF (inches)	8	41	0.05	>0.20	0.66	0.12	0.20	0.44	NO	NO	---
TSS (lbs/ac)	8	41	>0.20	>0.20	0.64	0.23	0.84	0.62	NO	NO	---
COD (lbs/ac)	7	39	>0.20	>0.20	0.61	*	0.16	0.62	NO	NO	---
TOTAL-P (lbs/ac)	5	41	>0.20	>0.20	0.57	0.22	0.69	0.57	NO	NO	---
ORTHO-P (lbs/ac)	7	37	>0.20	>0.20	0.19	0.14	0.18	0.16	NO	NO	---
TOTAL-N (lbs/ac)	6	41	0.15	>0.20	0.64	0.39	0.66	0.51	NO	NO	---
NITRATE-N (lbs/ac)	8	41	>0.20	>0.20	0.25	0.29	0.20	0.16	NO	NO	---
AMMONIA-N (lbs/ac)	8	41	>0.20	>0.20	0.40	0.28	0.39	0.31	NO	NO	---
TKN (lbs/ac)	6	41	>0.20	0.20	0.85	0.32	0.66	0.67	NO	NO	---
EPB (lbs/ac)	0	5	--	>0.20	--	--	--	--	--	--	---
PBF (lbs/ac)	1	--	--	--	--	--	--	--	--	--	---
EZN (lbs/ac)	8	34	>0.20	>0.20	*	0.11	*	*	NO	YES	GRASS SWALE
ECU (lbs/ac)	1	6	--	>0.20	--	--	--	--	--	--	---

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[1] Assumed Lognormal Distribution

*Level of Significance is less than 0.05

extractable zinc. For suspended solids, COD, and the plant nutrients, no difference in runoff loadings could be found between Dufief and Westleigh. To compensate for the small number of events monitored at Dufief, a final series of statistical tests was undertaken using the Stratton Woods and Dufief datasets pooled (e.g., representative of large lot single family land use). These results are presented in Table 45. The same runoff threshold applied to Stratton Woods was applied to the pooled datasets. Only two events from Dufief fell within this threshold. The results for the large lot single family datasets are identical to the previous findings: no significant difference in loadings between grass swale and curb and gutter sites.

Fairidge. Fairidge is the only medium density single family monitoring site which is served by roadside grass swales. Runoff loading data from Fairidge was compared to monitoring data from the Burke Pond Inflow station. For synoptic events, results of the statistical analyses are presented in Table 46. These results are consistent with the results from the large lot single family sites. No significant differences could be found between the grass swale and the curb and gutter datasets. Again, extractable zinc was the only exception; somewhat higher loadings of zinc are noted at the grass swale sites.

Complete datasets (i.e., non-synoptic) were also compared. These results are summarized in Table 47. The inclusion of non-synoptic events in these comparisons shows the grass swale loadings to be significantly higher for COD, ortho-P, ammonia-N, and extractable zinc. It is felt that these results are due to different hydrometeorologic conditions and that the use of synoptic datasets gives a better indication of comparative loadings.

Summary. No pollutant removal efficiencies could be quantified based on the monitoring data resulting from three NURP monitoring sites. Statistical tests between the loading datasets demonstrate that there are no significant differences between the pollutant loadings from these grass swale sites and synoptic loading datasets from curb and gutter of similar land uses. Given the low pollutant removal efficiencies projected for these BMP's, it is felt that much greater emphasis must be placed on selecting uncontrolled sites with which to compare grass swale runoff loadings. Finally, roadside grass swale must be designed so as to maximize runoff contact times within the swale area.

TABLE 45

COMPARISON OF GRASS SWALE vs. CURB & GUTTER RUNOFF STATISTICS: LARGE LOT SINGLE FAMILY[1,2] UNIT AREA LOADS

			PARAMETRIC STATISTICS[3] LEVEL OF SIGNIFICANCE				NONPARAMETRIC STATISTICS LEVEL OF SIGNIFICANCE		HYPOTHESIS		
			ONE-SIDED K-S TEST								
CONSTITUENT	N GRASS SWALE	N CURB & GUTTER	GRASS SWALE	CURB & GUTTER	T-STATISTIC ON MEANS	F-STATISTIC ON VARIANCES	TWO-SIDED K-S DISTRIBUTION TEST	WILCOXON RANK SUM MEDIAN TEST	SIGNIFICANTLY DIFFERENT DISTRIBUTION	SIGNIFICANTLY DIFFERENT MEAN OR MEDIAN	HIGHER MEAN/MEDIAN VALUE
RUNOFF (inches)	26	18	>0.20	0.10	0.21	0.58	>0.20	0.21	NO	NO	---
TSS (lbs/ac)	26	18	>0.20	>0.20	0.94	0.56	>0.20	0.90	NO	NO	---
COD (lbs/ac)	25	17	>0.20	0.20	0.30	0.48	0.10	0.12	NO	NO	---
TOTAL-P (lbs/ac)	23	18	0.05	>0.20	0.80	0.93	>0.20	0.49	NO	NO	---
ORTHO-P (lbs/ac)	26	14	>0.20	>0.20	0.41	0.96	>0.20	0.31	NO	NO	---
TOTAL-N (lbs/ac)	23	18	>0.20	>0.20	0.57	0.48	>0.20	0.44	NO	NO	---
NITRATE-N (lbs/ac)	26	18	>0.20	>0.20	0.68	0.55	>0.20	0.42	NO	NO	---
AMMONIA-N (lbs/ac)	26	18	0.10	>0.20	0.93	0.27	>0.20	0.61	NO	NO	---
TKN (lbs/ac)	23	18	0.15	0.15	0.33	0.46	>0.20	0.24	NO	NO	---
EPB (lbs/ac)	0	2	--	--	--	--	--	--	--	--	---
PBF (lbs/ac)	--	--	--	--	--	--	--	--	--	--	---
EZN (lbs/ac)	22	14	>0.20	0.15	*	0.43*	*	*	NO	YES	CURB & GUTTER
ECU (lbs/ac)	4	3	--	--	0.59	0.68	>0.20	1.0	NO	NO	---

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[1] Stratton Woods and Dufief Pooled
[2] Runoff Threshold 0.05" < Runoff < 0.6"
[3] Assumed Lognormal Distribution
*Level of Significance is less than 0.05

TABLE 46

COMPARISON OF GRASS SWALE vs. CURB & GUTTER RUNOFF STATISTICS: FAIRIDGE vs. BURKE POND INFLOW
SYNOPTIC EVENTS ONLY
MEDIUM DENSITY SINGLE FAMILY
UNIT AREA LOADS

CONSTITUENT	N GRASS SWALE	N CURB & GUTTER	PARAMETRIC STATISTICS[1] LEVEL OF SIGNIFICANCE: ONE-SIDED K-S TEST GRASS SWALE	ONE-SIDED K-S TEST CURB & GUTTER	T-STATISTIC ON MEANS	F-STATISTIC ON VARIANCES	NONPARAMETRIC STATISTICS LEVEL OF SIGNIFICANCE: TWO-SIDED K-S DISTRIBUTION TEST	WILCOXON RANK SUM MEDIAN TEST	HYPOTHESIS: SIGNIFICANTLY DIFFERENT DISTRIBUTION	SIGNIFICANTLY DIFFERENT MEAN OR MEDIAN	HIGHER MEAN/MEDIAN VALUE
RUNOFF (inches)	28	28	>0.20	>0.20	0.81	0.72	>0.20	0.70	NO	NO	---
TSS (lbs/ac)	25	27	0.10	>0.20	0.56	0.73	>0.20	0.76	NO	NO	---
COD (lbs/ac)	26	28	>0.20	>0.20	0.11	0.70	0.15	0.09	NO	NO	---
TOTAL-P (lbs/ac)	27	26	>0.20	>0.20	0.26	0.93	>0.20	0.28	NO	NO	---
ORTHO-P (lbs/ac)	26	25	>0.20	>0.20	0.13	0.62	>0.20	0.10	NO	NO	---
TOTAL-N (lbs/ac)	25	26	0.15	>0.20	0.55	0.31	>0.20	0.30	NO	NO	---
NITRATE-N (lbs/ac)	26	28	0.05	>0.20	0.78	0.76	>0.20	0.60	NO	NO	---
AMMONIA-N (lbs/ac)	27	27	>0.20	>0.20	0.10	0.85	0.10	*	NO	NO	---
TKN (lbs/ac)	27	26	>0.20	>0.20	0.36	0.31	0.10	0.21	NO	NO	---
EPB (lbs/ac)	0	0	--	--	--	--	--	--	--	--	---
PBF (lbs/ac)	--	--	--	--	--	--	--	--	--	--	---
EZN (lbs/ac)	27	16	>0.20	0.05	*	0.14	*	*	NO	YES	GRASS SWALE
ECU (lbs/ac)	6	6	0.10	0.05	0.29	0.24	>0.20	0.97	NO	NO	---

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[1] Lognormal Distribution Assumed
*Level of Significance is less than 0.05

TABLE 47

COMPARISON OF GRASS SWALE vs. CURB & GUTTER RUNOFF STATISTICS: FAIRIDGE vs. BURKE POND INFLOW
LAND USE; MEDIUM DENSITY SINGLE FAMILY
UNIT AREA LOADS

CONSTITUENT	N GRASS SWALE	N CURB & GUTTER	PARAMETRIC STATISTICS[1] LEVEL OF SIGNIFICANCE: ONE-SIDED K-S TEST GRASS SWALE	PARAMETRIC STATISTICS[1] LEVEL OF SIGNIFICANCE: ONE-SIDED K-S TEST CURB & GUTTER	PARAMETRIC STATISTICS[1] LEVEL OF SIGNIFICANCE: T-STATISTIC ON MEANS	PARAMETRIC STATISTICS[1] LEVEL OF SIGNIFICANCE: F-STATISTIC ON VARIANCES	NONPARAMETRIC STATISTICS LEVEL OF SIGNIFICANCE: TWO-SIDED K-S DISTRIBUTION TEST	NONPARAMETRIC STATISTICS LEVEL OF SIGNIFICANCE: WILCOXON RANK SUM MEDIAN TEST	HYPOTHESIS: SIGNIFICANTLY DIFFERENT DISTRIBUTION	HYPOTHESIS: SIGNIFICANTLY DIFFERENT MEAN OR MEDIAN	HYPOTHESIS: HIGHER MEAN/MEDIAN VALUE
RUNOFF (inches)	50	60	>0.20	0.10	0.47	0.97	0.71	0.55	NO	NO	---
TSS (lbs/ac)	47	57	>0.20	>0.20	0.47	0.43	0.64	0.45	NO	NO	---
COD (lbs/ac)	48	59	>0.20	>0.20	*	0.28	0.05	*	NO	YES	GRASS SWALE
TOTAL-P (lbs/ac)	47	57	0.20	0.15	0.08	0.69	0.29	0.10	NO	NO	---
ORTHO-P (lbs/ac)	48	56	>0.20	>0.20	*	0.71	0.05	*	NO	YES	GRASS SWALE
TOTAL-N (lbs/ac)	44	58	>0.20	>0.20	0.16	0.15	0.18	0.13	NO	NO	---
NITRATE-N (lbs/ac)	48	60	>0.20	0.20	0.20	0.40	0.22	0.18	NO	NO	---
AMMONIA-N (lbs/ac)	49	59	>0.20	>0.20	*	0.57	*	*	NO	YES	GRASS SWALE
TKN (lbs/ac)	46	58	>0.20	>0.20	0.08	0.21	0.05	0.07	NO	NO	---
EPB (lbs/ac)	1	2	--	--	--	--	--	--	--	--	---
PBF(lbs/ac)	--	--	--	--	--	--	--	--	--	--	---
EZN (lbs/ac)	44	40	>0.20	>0.20	*	0.31	*	*	NO	YES	GRASS SWALE
ECU (lbs/ac)	9	11	0.10	>0.20	0.50	0.47	1.00	0.98	NO	NO	---

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[1] Assumed Lognormal Distribution

*Level of Significance is less than 0.05

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ADDENDUM, 11-14-84

WASHINGTON METROPOLITAN AREA

URBAN RUNOFF DEMONSTRATION PROJECT

A FINAL REPORT

April 1983

The Appendix pages (except for the title pages), computer-generated, have been deleted due to their poor, largely unreadable quality. An attempt was made to obtain replacement copies, but those pages were of even poorer quality, and proved completely unsatisfactory. The title pages for Appendices A-F have been included to show the type of information each Appendix contained. Monitoring data should be included in the NURP STORET files. For other information, contact The Metropolitan Washington Council of Governments, 1875 Eye Street, N.W., Washington, D.C. 20006.

APPENDIX A

LISTING OF RUNOFF MONITORING DATA
RUNOFF VOLUME, TSS, COD, N AND P

KEY

STATIONS:

51UR03	Burke Ponds (wet pond) Inflow
51UR04	Burke Ponds Outflow
51UR05	Dandridge (infiltration)
51UR06	Stratton Woods (roadside swale)
51UR07	Lake Ridge (detention pond) Inflow
51UR08	Lake Ridge Outflow
51UR09	Fairidge (roadside swale)
51UR10	Stedwick (modified detention pond) Inflow
51UR11	Stedwick Outflow
51UR15	Westleigh (wet pond) Inflow
51UR16	Westleigh Outflow
51UR17	Burke Village Center (infiltration)
51UR19	Rockville Village Center (infiltration)

VARIABLES:

STA	Station
STRMNO	Storm Number (Julian calendar day)
TIME	Sample Time (S.D.) or Start Time (Comp.)
MODE	S.D. = Sequential Discrete Sample Comp. = Composite Sample
FLO	Instantaneous flow rate (cfs) for S.D. mode; For Comp. mode, average flow rate (cfs) between first and last sample based upon NVPDC integration of VPI&SU flow file
COD	Chemical Oxygen Demand (mg/l)
TSS	Total Suspended Solids (mg/l)
TN	Total Nitrogen (mg/l as N)
TKN	Total Kjeldahl Nitrogen (mg/l as N)
SKN	Soluble Kjeldahl Nitrogen (mg/l as N)
NH3	Ammonia Nitrogen (mg/l as N)
NO23	Nitrite plus Nitrate Nitrogen (mg/l as N)
TP	Total Phosphorus (mg/l as P)
TSP	Total Soluble Phosphorus (mg/l as P)
OP	Ortho-Phosphorus (mg/l as P)

APPENDIX B

LISTING OF RUNOFF MONITORING DATA
HEAVY METALS

KEY

STATIONS:

51UR03	Burke Ponds (wet pond) Inflow
51UR04	Burke Ponds Outflow
51UR05	Dandridge (infiltration)
51UR06	Stratton Woods (roadside swale)
51UR07	Lake Ridge (detention pond) Inflow
51UR08	Lake Ridge Outflow
51UR09	Fairidge (roadside swale)
51UR10	Stedwick (modified detention pond) Inflow
51UR11	Stedwick Outflow
51UR15	Westleigh (wet pond) Inflow
51UR16	Westleigh Outflow
51UR17	Burke Village Center (infiltration)
51UR19	Rockville Village Center (infiltration)

VARIABLES:

STA	Station
STRMNO	Storm Number (Julian calendar day)
TIME	Sample Time (S.D.) or Start Time (Comp.)
MODE	S.D. = Sequential Discrete Sample Comp. = Composite Sample
EPB	Extractable Lead (ug/l)
SPB	Dissolved Lead (ug/l)
EZN	Extractable Zinc (ug/l)
SZN	Dissolved Zinc (ug/l)
ECU	Extractable Copper (ug/l)
SCU	Dissolved Copper (ug/l)
EMN	Extractable Manganese (ug/l)
SMN	Dissolved Manganese (ug/l)
EFE	Extractable Iron (ug/l)
SFE	Dissolved Iron (ug/l)
ECR	Extractable Chromium (ug/l)
SCR	Dissolved Chromium (ug/l)
ECD	Extractable Cadmium (ug/l)
SCD	Dissolved Cadmium (ug/l)
ENI	Extractable Nickel (ug/l)
SNI	Dissolved Nickel (ug/l)

NOTE: EPB and SPB indicate analysis by flame AA; PBF and SPBF indicate analysis by furnace AA

APPENDIX C

COMPARISONS OF STORM EVENT MEAN CONCENTRATIONS IN NURP AND 208 DATASETS

APPENDIX D

COMPARISONS OF STORM EVENT UNIT AREA LOADS IN NURP AND 208 DATASETS

APPENDIX E

COMPARISON OF DISSOLVED AND INORGANIC FRACTION IN NURP AND 208 DATASETS

APPENDIX F

LISTING OF WETFALL MONITORING DATA

VARIABLE	EXPLANATION
STA	Station
TI1	Time at which station was activated for sample collection
TI2	Time at which sampling period ended
LCOND	Laboratory conductivity (uhos)
LPH	Laboratory pH
COD	Chemical oxygen demand (mg/l)
BOD5	Five-day BOD (mg/l)
TKN	Total kjeldahl nitrogen (mg/l as N)
SKN	Dissolved kjeldahl nitrogen (mg/l as N)
NH3	Ammonia nitrogen (mg/l as P)
NO23	Nitrite plus nitrate N (mg/l as N)
TP	Total phosphorus (mg/l as P)
TSP	Total dissolved phosphorus (mg/l as P)
OP	Ortho-phosphorus (mg/l as P)
EPB*	Extractable lead (ug/l)
SPB	Dissolved lead (ug/l)
EZN	Extractable zinc (ug/l)
SZN	Dissolved zinc (ug/l)
EMN	Extractable manganese (ug/l)
SMN	Dissolved manganese (ug/l)
ECU	Extractable copper (ug/l)
SCU	Dissolved copper (ug/l)
ECR	Extractable chromium (ug/l)
SCR	Dissolved chromium (ug/l)
ECD	Extractable cadmium (ug/l)
SCD	Dissolved cadmium (ug/l)
ENI	Extractable nickel (ug/l)
SNI	Dissolved nickel (ug/l)

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*"Z" prefix indicates zero heavy metal values reset to detection limits

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